T. Bradley Sc.

Present state of the Temple of Serapis at Puzzuoli.

London. Published by John Murray, Albemarle St June 182

1. Montagnolo. 2. Torre del filosofo. 3. Highest Cone. 4. Lepra. 5. Finocchio. 6. Capra. 7. Cone of 1811 8 Cima del asino. 9. Musarra.

View of the Valle del Bove Etna.

Wm Walker February 8th 1833

PRINCIPLES

OF

GEOLOGY,

BEING

AN ATTEMPT TO EXPLAIN THE FORMER CHANGES OF THE EARTH'S SURFACE,

BY REFERENCE TO CAUSES NOW IN OPERATION.

BY

CHARLES LYELL, Esq., F.R.S.,

FOR. SEC. TO THE GEOL. SOC., PROF. OF GEOL. TO KING'S COLL., LONDON.

'Amid all the revolutions of the globe the economy of Nature has been uniform, and her laws are the only things that have resisted the general movement. The rivers and the rocks, the seas and the continents have been changed in all their parts; but the laws which direct those changes, and the rules to which they are subject, have remained invariably the same.'

PLAYFAIR, *Illustrations of the Huttonian Theory*, § 374.

THE SECOND EDITION.

LONDON:
JOHN MURRAY, ALBEMARLE-STREET.

MDCCCXXXII.

TO THE

VERY REVEREND

WILLIAM BUCKLAND, D.D., F.R.S., F.G.S.,

&c. &c. &c.

PROFESSOR OF GEOLOGY IN THE UNIVERSITY OF OXFORD.

MY DEAR DR. BUCKLAND,

The favourable reception of the first edition encourages me to offer the dedication of this volume to you, who first instructed me in the elements of Geology, and by whose energy and talents the cultivation of the science in this country has been so eminently promoted.

I am,

My dear Dr. BUCKLAND,

Very sincerely yours,

CHARLES LYELL.

London, June 10, 1832.

TO

WILLIAM JOHN BRODERIP, Esq., B. A.

BARRISTER AT LAW,

F.R.S., F.L.S., ETC.,

VICE PRESIDENT OF THE GEOLOGICAL SOCIETY OF LONDON.

My Dear Friend,

In dedicating this volume to you, I am glad of an opportunity of acknowledging the kind interest which you have uniformly taken in the success of my labours, and the valuable assistance which you have afforded me in several departments of Natural History.

I am,

My Dear Friend,

Yours, very sincerely,

Charles Lyell.

London, December 8*th*, 1831.

TO

RODERICK IMPEY MURCHISON, Esq., F.R.S.,

&c. &c. &c.

LATE PRESIDENT OF THE GEOLOGICAL SOCIETY.

My dear Murchison,

I have great pleasure in dedicating this volume to you, as it contains the results of some of our joint labours in the field, in Auvergne, Velay, and Piedmont—results which had not yet been communicated to the public through any other channel.

When we quitted England together for a tour on the continent, in May, 1828, the first sketch only of my 'Principles of Geology' was finished. Since that time you have watched the progress of the work with friendly interest, and, as President of the Geological Society, have twice expressed in your Anniversary Addresses, your participation in many of my views, which were warmly controverted by others. The eulogy which you have lately pronounced from the chair, on the last part of my work, (whether I attribute your approval to the exercise of an unbiassed judgment or to the partiality of a friend,) could not fail to be most gratifying to my feelings, and I trust that you will long enjoy health and energy to continue to promote with enthusiasm the advancement of your favourite science.

Believe me, my dear Murchison,

Yours, &c. &c.

Charles Lyell.

PREFACE.

In the Preface to the first edition of this volume the author stated that he had found it impossible to compress into two volumes, according to the original plan of his work, the wide range of subjects which it was necessary to discuss in order fully to explain his theoretical views. He therefore determined to extend the 'Principles of Geology' to three volumes. The last of these is now in the press, and will very shortly be laid before the public.

London, December 7th, 1832.

The original MS. of the 'Principles of Geology' was delivered to the publisher at the close of the year 1827, when it was proposed that it should appear in the course of the year following, in two volumes octavo. Since that time many causes have concurred to delay the completion of the work, and, in some degree, to modify the original plan. In May, 1828, when the preliminary chapters on the History of Geology, and some others which follow them in the first volume, were nearly finished, I became anxious to visit several parts of the continent, in order to acquire more information concerning the tertiary formations. Accordingly, I set out in May, 1828, in company with Mr. Murchison, on a tour through France and the north of Italy, where we examined together many districts which are particularly mentioned in the body of this work. We visited Auvergne, Velay, Cantal, and the Vivarais, and afterwards the environs of Aix, in Provence, and then passed by the Maritime Alps to Savona, thence crossing to Piedmont by the Valley of the Bormida.

At Turin we found Signor Bonelli engaged in the arrangement of a large collection of tertiary shells

obtained chiefly from the Italian strata; and as I had already conceived the idea of classing the different tertiary groups, by reference to the proportional number of recent species found fossil in each, I was at pains to learn what number Signor Bonelli had identified with living species, and the degree of precision with which such identifications could be made. With a view of illustrating this point, he showed us suites of shells common to the Subapennine beds and to the Mediterranean, pointing out that in some instances not only the ordinary type of the species, but even the different varieties had their counterparts both in the fossil and recent series. The same naturalist informed us that the fossil shells of the hill of the Superga, at Turin, differed as a group from those of Parma and other localities of the Subapennine beds of northern Italy; and, on the other hand, that the characteristic shells of the Superga agreed with the species found at Bordeaux and other parts of the South of France.

I was the more struck with this remark, as Mr. Murchison and myself had already inferred that the highly-inclined strata of the Valley of the Bormida, which agree with those of the Superga, were older than the more horizontal Subapennine marls, by which the plains of the Tanaro and the Po are skirted.

When we had explored some parts of the Vicentin together, Mr. Murchison re-crossed the Alps, while I directed my course to the south of Italy, first staying

at Parma, where I studied, in the cabinets of Signor Guidotti, a beautiful collection of Italian tertiary shells, consisting of more than 1000 species, many of which had been identified with living testacea. Signor Guidotti had not examined his fossils with reference to their bearing on geological questions, but computed, on a loose estimate, that there were about 30 per cent. of living species in the Subapennine beds. I then visited Florence, Sienna, and Rome, and the results of my inquiries respecting the tertiary strata of those territories will be found partly in the body of the work, and partly in the catalogues given in Appendix II.

On my arrival at Naples I became acquainted with Signor O. G. Costa, who had examined the fossil shells of Otranto and Calabria, and had collected many recent testacea from the seas surrounding the Calabrian coasts. His comparison of the fossil and living species had led him to a very different result in regard to the southern extremity of Italy, from that to which Signors Guidotti and Bonelli had arrived in regard to the north, for he was of opinion that few of the tertiary shells were of extinct species. In confirmation of this view, he showed me a suite of fossil shells from the territory of Otranto, in which nearly all the species were recent.

In October, 1828, I examined Ischia, and obtained from the strata of that island the fossil shells named in Appendix II., p. 57. They were all, with two or

three exceptions, recognized by Signor Costa as species now inhabiting the Mediterranean, a circumstance which greatly astonished me, as I procured some of them at the height of 2000 feet above the level of the sea (Vol. iii. p. 126).

Early in November, 1828, I crossed from Naples to Messina, and immediately afterwards examined Etna, and collected on the flanks of that mountain, near Trezza, the fossil shells alluded to in the third volume (p. 79, and Appendix II., p. 53). The occurrence of shells in this locality was not unknown to the naturalists of Catania, but having been recognized by them as *recent* species, they were supposed to have been carried up from the sea-shore to fertilize the soil, and therefore disregarded. Their position is well known to many of the peasants of the country, by whom the fossils are called 'roba di diluvio.'

In the course of my tour I had been frequently led to reflect on the precept of Descartes, 'that a philosopher should once in his life doubt every thing he had been taught;' but I still retained so much faith in my early geological creed as to feel the most lively surprise, on visiting Sortino, Pentalica, Syracuse, and other parts of the Val di Noto, at beholding a limestone of enormous thickness filled with recent shells, or sometimes with the mere casts of shells, resting on marl in which shells of Mediterranean species were imbedded in a high state of preservation. All idea of attaching a high antiquity to a regularly stratified

limestone, in which the casts and impressions of shells alone were discernible, vanished at once from my mind. At the same time, I was struck with the identity of the associated igneous rocks of the Val di Noto with well known varieties of 'trap' in Scotland and other parts of Europe, varieties, which I had also seen entering largely into the structure of Etna. I occasionally amused myself with speculating on the different rate of progress which Geology might have made, had it been first cultivated with success at Catania, where the phenomena above alluded to, and the great elevation of the modern tertiary beds in the Val di Noto, and the changes produced in the historical era by the Calabrian earthquakes, would have been familiarly known.

From Cape Passaro I passed on by Spaccaforno and Licata to Girgenti, where I abandoned my design of exploring the western part of Sicily, that I might return again to the Val di Noto and the neighbourhood of Etna, and verify the discoveries which I had made. With this view I travelled by Caltanisetta, Piazza, Caltagirone, Vizzini, Militello, Palagonia, Lago Naftia, and Radusa, to Castrogiovanni, and from thence to Palermo, at which last place I procured the shells named in Appendix II. p. 55. The sections on this new route confirmed me in my first opinions respecting the Val di Noto, as will appear by the 6th, 8th, and 9th chapters of the third Volume.

When I again reached Naples, in January, 1829, I

found that Signor O. G. Costa had examined the tertiary fossils which I had sent to him from different parts of Sicily, and declared them to be for the most part of recent species. I then bent my course homeward, seeing at Genoa, Professor Viviani and Dr. Sasso, the last of whom put into my hands his memoirs on the strata of Albenga (see vol. iii. p. 166), in which I found, that, according to his list of shells, the tertiary formations at the foot of the maritime Alps contained about 50 per cent. of recent species.

I next re-visited Turin, and communicated to Signor Bonelli the result of my inquiries respecting the tertiary beds of the south of Italy, and of Sicily, upon which he kindly offered to review his fossils, some of which had been obtained from those countries, and to compare them with the Subapennine shells of northern Italy. He also promised to draw up immediately a list of the shells characteristic of the greensand of the Superga, and common to that locality and Bordeaux, that I might publish it at the end of my second volume; but the death of this amiable and zealous naturalist soon afterwards deprived me of the benefit of his assistance.

I had now fully decided on attempting to establish four sub-divisions of the great tertiary epoch, the same which are fully illustrated in the present work. I considered the basin of Paris and London to be the type of the first division; the beds of the Superga, of the second; the Subapennine strata of northern Italy,

of the third; and Ischia and the Val di Noto, of the fourth. I was also convinced that I had seen proofs, during my tour in Auvergne, Tuscany and Sicily, of volcanic rocks contemporaneous with the sedimentary strata of three of the above periods.

On my return to Paris, in February, 1829, I communicated to M. Desnoyers some of the new views to which my examination of Sicily had led me, and my intention to attempt a classification of the different tertiary formations in chronological order, by reference to the comparative proportion of living species of shells found fossil in each. He informed me, that during my tour he had been employed in printing the first part of his memoir, not yet published, 'on the Tertiary Formations more recent than the Paris basin,' in which he had insisted on the doctrine 'of the succession of tertiary formations of different ages.' At the end of the first part of his memoir, which was published before I left Paris *, he annexed a note on the accordance of many of my views with his own, and my intention of arranging the tertiary formations chronologically, according to the relative number of fossils in each group, which were identifiable with species now living.

At the same time I learned from M. Desnoyers, that M. Deshayes had, by the mere inspection of the fossil shells in his extensive museum, convinced himself that the different tertiary formations might be

* Ann. des Sci. Nat., tome xvi. p. 214.

arranged in a chronological series. I accordingly lost no time in seeing M. Deshayes, who explained to me the data on which he considered that the three tertiary periods mentioned in the Tables, Appendix I., might be established. I at once perceived that the fossils obtained by me in my tour would form but an inconsiderable contribution to so great a body of zoological evidence as M. Deshayes had already in his possession. I therefore requested him to examine my shells when they arrived from Italy, and expressed my great desire to obtain his co-operation in my work, in which, as will appear in the sequel, I was fortunate enough to succeed.

The preparation of my first volume had now been suspended for nine months, and was not resumed until my return to London in the beginning of March, 1829. Before the whole was printed another summer arrived, and I again took the field to examine 'the Crag,' on the coasts of Essex, Norfolk, and Suffolk. The first volume appeared at length in January, 1830, after which I applied myself to perfect what I had written on 'the changes in the organic world,' a subject which merely occupied four or five chapters in my original sketch, but which was now expanded into a small treatise. Before this part was completed another summer overtook me, and I then set out on a geological expedition to the south of France, the Pyrenees, and Catalonia.

On my return to Paris, in September, 1830, I

studied for six weeks in the museum of M. Deshayes, examining his collection of fossil and recent shells, and profiting by his instructions in conchology. As he had not yet published any of the general results deducible from his valuable collection, I requested him to furnish me with lists of those species of shells which were common to two or more tertiary periods, as also the names of those known to occur both in some tertiary strata and in a living state. This he engaged to do, and we agreed that the information should be communicated in a tabular form. After several modifications of the plan first proposed for the Tables, we finally agreed upon the manner in which they should be constructed, and the execution was left entirely in the hands of M. Deshayes, in whose name they were to appear in my second volume.

The tables were sent to me in the course of the following spring (1831), and additions and corrections several months later. They contained not only the information which I had expected, but much more, for the names of several hundred species were added, as being common to two or more *formations* of the same *period*, whereas it was originally proposed to insert those only which were known to be common to two or more *distinct periods*. Thus, for example, more than 50 shells are now included in the tables, on the ground that they are common to the tertiary strata both of the London and Paris basins, although they

only occur in the *Eocene period* to which the strata of those basins belong. The names thus added will increase the value of the tables, and give a more complete view of the point to which fossil conchology has now reached; at the same time, it must be admitted that tables of shells cannot be perfected on this plan, as the science advances from year to year, without soon outgrowing the space which could reasonably be allotted to fossil conchology in a work on geology, for they would soon embrace the names of the greater number of known shells, nearly all of these being common to different groups of strata of the *same period.* Some of the catalogues which I have given in Appendix II., of fossil shells from the neighbourhood of the Red Sea, and from some other localities, may illustrate this remark, as they lead us to anticipate that, at no distant time, we may find a large proportion of all the *Recent* species in a fossil state.

In *treatises on fossil conchology,* such as I trust M. Deshayes will soon publish, we cannot have too complete a catalogue of all the species which have been found fossil in every locality, together with their synonyms; but in geological works we can only illustrate the more important theoretical points by catalogues of those shells which are either characteristic of particular periods, as being exclusively confined to them, or which show the connexion of two periods, by being common to each. For this purpose we

must select certain normal groups which do not approximate too closely to each other, and enumerate by name the species common to more than one of these. Thus, for example, we might omit in our tables the Newer Pliocene formations altogether, and enumerate the shells common to the Recent and Older Pliocene beds.

I have arranged the tertiary formations in four groups, as I had determined to do before I was acquainted with M. Deshayes; and in his tables he has referred the shells to three periods, according to which he had classed them before he had any communication with me. No confusion, however, will arise from this want of conformity between the tables and my classification, since I have named two of my periods (the Newer and Older Pliocene) as subdivisions of one of his; and by reference to the Synoptical Table, at p. 61, the reader will see which localities mentioned in M. Deshayes's Tables belong to the Newer and which to the Older Pliocene period.

In the summer of 1831 I made a geological excursion to the volcanic district of the Eifel, and on my return I determined to extend my work to three volumes, the second of which appeared in January, 1832. The last volume has been delayed till now by many interruptions, among which I may mention a tour, in the summer of 1832, up the valley of the Rhine, when I examined the loess (vol. iii. p. 151),

and a visit, on my way home through Switzerland, to the Valorsine, where I had an opportunity of verifying the observations of M. Necker on the granite veins and altered stratified rocks of that district. I may also mention the time occupied in the correction of the second edition of the first and second volumes, and the delivery of a course of Lectures in May and June, 1832, at King's College, London, on which occasion I had an opportunity of communicating to the scientific world a great part of the views now explained in my last volume.

London, April, 1833.

ADVERTISEMENT.

I HAVE availed myself of the present opportunity to make occasional corrections and additions throughout the work. The additions, however, are not considerable, the increased size of the volume being chiefly due to the adoption of a more open type, and the insertion of headings to the different subdivisions of each chapter, which it is hoped will facilitate reference, and render the arrangement of the subject-matter more clear to the student.

CONTENTS.

CHAPTER XXVI.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER XII.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XVIII.

ERRATA.

Frontispiece, *for* Montagnola, *read* Montagnuola.
Page 86, line 2 from bottom, *for* erigiron, *read* erigeron.
141, — 5 do. — *irridana*, — *viridana*.
219, — 17 do. — *gulæ*, — *gale*.
Map, *for* p. 304, *read* p. 312.

CHAPTER I.

CHAPTER II.

CHAPTER III.

LIST OF PLATES AND WOOD-CUTS

PLATES.

Frontispiece. View of the volcanos around Olot, in Catalonia. See p. 186. This view is taken from a sketch by the author; an attempt is made to represent by colours the different geological formations of which the country is composed. The blue line of mountains in the distance are the Pyrenees, which are to the north of the spectator, and consist of primary and ancient secondary rocks. In front of these are the secondary formations, described in chap. xiv., coloured purplish-grey of different tints, to express different distances. The flank of the hill, in the foreground, called Costa di Pujou, is composed partly of secondary rocks, which are seen to the left of a small bridle-road, and partly of volcanic, the red colour expressing lava and scoriæ.

Several very perfect volcanic cones, chiefly composed of red scoriæ, and having craters on their summits, are seen in the immediate neighbourhood of Olot, coloured red. The level plain on which that town stands has clearly been produced by the flowing down of many lava-streams from those hills into the bottom of a valley, probably once of considerable depth, like those of the surrounding country, but which has been in a great measure filled up by lava.

The reader should be informed, that in many impressions of this plate Montsacopa is mis-spelt 'Montescopa,' and Mount Garrinada is mis-spelt 'Gradenada.'

Plate I. The shells represented in this plate have been selected by M. Deshayes as characteristic of the Pliocene period of the Tables, Appendix I. The greater part of them are common both to the older and newer Pliocene periods of this work. Eight of the species, Nos. 1, 3, 5, 6, 7, 9, 13, and 14, are now living, but are given as being also found in the *Older* Pliocene formations. Fusus crispus is not found either *recent*

or in the Miocene or Eocene formations, but occurs both in the Newer and Older Pliocene strata. Mitra plicatula has been found only in the older Pliocene deposits. The Turbo rugosus was considered as exclusively Pliocene when selected by M. Deshayes, but M. Boué has since found it in the Miocene strata at Vienna and Moravia (see Tables, Appendix I. p. 26). Buccinum semistriatum is also a Miocene shell, but was inserted as being peculiarly abundant in the Pliocene strata.

Plate II. All the shells figured in this plate, except Cardita Ajar, are very characteristic of the Miocene formations; that is to say, they are found in that period and no other. Cardita Ajar is also very common in the Miocene strata, but is also a Recent species. It has not yet been observed in any *Pliocene* deposit.

Plate III. The species of shells figured in this plate are characteristic of the Eocene period, as being exclusively confined to deposits of that period, and for the most part abundant in them.

Plate IV. The microscopic shells of the order Cephalopoda, figured in this plate, are characteristic of the Eocene period, and are distinct from the microscopic shells of the Older Pliocene formations of Italy. The figures are from unpublished drawings by M. Deshayes, who has selected some of the most remarkable types of form. The reader will observe, that the minute points, figures 4, 8, 11, 14, and 18, indicate the natural size of the species which are represented. (For observations on these shells see p. 251.)

Plate V. Geological Map of the south-east of England, exhibiting the Denudation of the Weald. This map has been compiled in great part from Mr. Greenough's Geological Map of England, and Mr. Mantell's Map of the south-east of England. (Illustrations of Geol. of Sussex, and fossils of Tilgate Forest, 1827.) The eastern extremity of the 'denudation' is reduced from Mr. Murchison's Map of that district. (Geol. Trans., 2nd series, vol. ii. part i. plate 14.) The object of this map is fully explained in chapters xxi. and xxii. of this volume.

LIST OF PLATES AND WOOD-CUTS

PLATES.

Frontispiece.—This representation of the present state of the Temple of Serapis has been carefully reduced from that given by the Canonico Andrea de Jorio in his 'Ricerche sul Tempio di Serapide, in Puzzuoli.' Napoli, 1820.

Plate I. *fig.* 1.—Showing that a chain of volcanic vents surrounds the Asiatic Islands, in the same manner as a continuation of the same line skirts the eastern borders of the continent of Asia. This plate is copied from plate 13 of Von Buch's Phys. Besch. der Canarischen Inseln. Berlin, 1825. The position, however, of some of the volcanos, and the outline of several of the islands, has been corrected.

Fig. 2.—Showing the direction of the trachytic islands from N.W. to S.E. parallel to the principal mountain-chains of Greece, as also to the Grecian islands which constitute a continuation of the mountains of the main land, and are of the same mineral composition. This plate is also copied from Von Buch, plate 12, p. 365.

Plate II. *fig.* 1.—View of the islands of Ischia and Procida, with part of the coast of Misenum, taken from part of plate 17 of Sir William Hamilton's Campi Phlegræi.

Fig. 2.—Map of the Volcanic district of Naples. This map is copied from one constructed by G. P. Scrope, Esq., to illustrate a memoir in the Geol. Trans., vol. ii. part iii., from unpublished maps of Captain Smyth, R.N., p. 375.

WOOD-CUTS.

LIST OF WOOD-CUTS.

PRINCIPLES OF GEOLOGY.

CHAPTER I.

Geology defined—Compared to History—Its relation to other Physical Sciences—Its distinctness from all—Not to be confounded with Cosmogony.

Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature; it inquires into the causes of these changes, and the influence which they have exerted in modifying the surface and external structure of our planet.

By these researches into the state of the earth and its inhabitants at former periods, we acquire a more perfect knowledge of its *present* condition, and more comprehensive views concerning the laws *now* governing its animate and inanimate productions. When we study history we obtain a more profound insight into human nature, by instituting a comparison between the present and former states of society. We trace the long series of events which have gradually led to the actual posture of affairs; and by connecting effects with their causes, we are enabled to classify and retain in the memory a multitude of complicated relations—the various peculiarities of national character—the different degrees of moral and intellectual refinement, and numerous other circumstances, which, without historical associations, would be uninteresting or imperfectly understood. As the present condition of nations is the result of many antecedent changes, some extremely remote and others recent, some gradual, others sudden and violent, so the state of the natural world is the result of a long succession of events, and if we would enlarge

our experience of the present economy of nature, we must investigate the effects of her operations in former epochs.

We often discover with surprise, on looking back into the chronicles of nations, how the fortune of some battle has influenced the fate of millions of our contemporaries, when it has long been forgotten by the mass of the population. With this remote event we may find inseparably connected the geographical boundaries of a great state, the language now spoken by the inhabitants, their peculiar manners, laws, and religious opinions. But far more astonishing and unexpected are the connexions brought to light, when we carry back our researches into the history of nature. The form of a coast, the configuration of the interior of a country, the existence and extent of lakes, valleys, and mountains, can often be traced to the former prevalence of earthquakes and volcanos, in regions which have long been undisturbed. To these remote convulsions the present fertility of some districts, the sterile character of others, the elevation of land above the sea, the climate, and various peculiarities, may be distinctly referred. On the other hand, many distinguishing features of the surface may often be ascribed to the operation at a remote era of slow and tranquil causes—to the gradual deposition of sediment in a lake or in the ocean, or to the prolific increase of testacea and corals therein.

To select another example, we find in certain localities subterranean deposits of coal, consisting of vegetable matter, formerly drifted into seas and lakes. These seas and lakes have since been filled up, the lands whereon the forests grew have disappeared or changed their form, the rivers and currents which floated the vegetable masses can no longer be traced, and the plants belonged to species which for ages have passed away from the surface of our planet. Yet the commercial prosperity, and numerical strength of a nation, may now be mainly dependent on the local distribution of fuel determined by that ancient state of things.

Geology is intimately related to almost all the physical

sciences, as is history to the moral. An historian should, if possible, be at once profoundly acquainted with ethics, politics, jurisprudence, the military art, theology; in a word, with all branches of knowledge, whereby any insight into human affairs, or into the moral and intellectual nature of man, can be obtianed. It would be no less desirable that a geologist should be well versed in chemistry, natural philosophy, mineralogy, zoology, comparative anatomy, botany; in short, in every science relating to organic and inorganic nature. With these accomplishments the historian and geologist would rarely fail to draw correct and philosophical conclusions from the various monuments transmitted to them of former occurrences. They would know to what combination of causes analogous effects were referrible, and they would often be enabled to supply by inference, information concerning many events unrecorded in the defective archives of former ages. But the brief duration of human life, and our limited powers, are so far from permitting us to aspire to such extensive acquisitions, that excellence even in one department is within the reach of few, and those individuals most effectually promote the general progress, who concentrate their thoughts on a limited portion of the field of inquiry.

As it is necessary that the historian and the cultivators of moral or political science should reciprocally aid each other, so the geologist and those who study natural history or physics stand in equal need of mutual assistance. A comparative anatomist may derive some accession of knowledge from the bare inspection of the remains of an extinct quadruped, but the relic throws much greater light upon his own science, when he is informed to what relative era it belonged, what plants and animals were its contemporaries, in what degree of latitude it once existed, and other historical details. A fossil shell may interest a conchologist, though he be ignorant of the locality from which it came; but it will be of more value when he learns with what other species it was associated, whether they were marine or fresh-water, whether the strata

containing them were at a certain elevation above the sea, and what relative position they held in regard to other groups of strata, with many other particulars determinable by an experienced geologist alone. On the other hand, the skill of the comparative anatomist and conchologist are often indispensable to those engaged in geological research, although it will rarely happen that the geologist will himself combine these different qualifications in his own person.

Some remains of former organic beings, like the ancient temple, statue, or picture, may have both their intrinsic and their historical value, while there are others which can never be expected to attract attention for their own sake. A painter, sculptor, or architect, would often neglect many curious relics of antiquity, as devoid of beauty and uninstructive with relation to their own art, however illustrative of the progress of refinement in some ancient nation. It has therefore been found desirable that the antiquary should unite his labours to those of the historian, and similar co-operation has become necessary in geology.

The field of inquiry in living nature being inexhaustible, the zoologist and botanist can rarely be induced to sacrifice time in exploring the imperfect remains of lost species of animals and plants, while those still existing afford constant matter of novelty. They must entertain a desire of promoting *geology* by such investigations, and some knowledge of its objects must guide and direct their studies. According to the different opportunities, tastes, and talents of individuals, they may employ themselves in collecting particular kinds of minerals, rocks, or organic remains, and these, when well examined and explained, afford data to the geologist, as do coins, medals, and inscriptions to the historian.

It was long ere the distinct nature and legitimate objects of geology were fully recognized, and it was at first confounded with many other branches of inquiry, just as the limits of history, poetry, and mythology were ill-defined in the infancy of civilization. Werner appears to have regarded geology as

little other than a subordinate department of mineralogy, and Desmarest included it under the head of Physical Geography. But the identification of its objects with those of Cosmogony has been the most common and serious source of confusion. The first who endeavoured to draw a clear line of demarcation between these distinct departments, was Hutton, who declared that geology was in no ways concerned 'with questions as to the origin of things.'

We shall attempt in the sequel of this work to demonstrate that geology differs as widely from cosmogony, as speculations concerning the creation of man differ from history. But before we enter more at large on this controverted question, we shall endeavour to trace the progress of opinion on this topic, from the earliest ages, to the commencement of the present century.

CHAPTER II.

Oriental Cosmogony—Doctrine of the successive destruction and renovation of the world—Origin of this doctrine—Common to the Egyptians—Adopted by the Greeks—System of Pythagoras—Of Aristotle—Dogmas concerning the extinction and reproduction of genera and species—Strabo's theory of elevation by earthquakes—Pliny—Concluding Remarks on the knowledge of the Ancients.

Oriental Cosmogony. THE earliest doctrines of the Indian and Egyptian schools of philosophy, agreed in ascribing the first creation of the world to an omnipotent and infinite Being. They concurred also in representing this Being, who had existed from all eternity, as having repeatedly destroyed and reproduced the world and all its inhabitants. In the 'Institutes of Menù,' the sacred volume of the Hindoos, to which, in its present form, Sir William Jones ascribes an antiquity of at least eight hundred and eighty years before Christ, we find this system of the alternate destruction and renovation of the world, proposed in the following remarkable verses.

'The Being, whose powers are incomprehensible, having created me (Menù) and this universe, again became absorbed in the supreme spirit, changing the time of energy for the hour of repose.

'When that power awakes, then has this world its full expansion; but when he slumbers with a tranquil spirit, then the whole system fades away..... For while he reposes as it were, embodied spirits endowed with principles of action depart from their several acts, and the mind itself becomes inert.'

Menù then describes the absorption of all beings into the Supreme essence, and the Divine soul itself is said to slumber, and to remain for a time immersed in 'the first idea, or in darkness.' He then proceeds, (verse fifty-seven,) 'Thus that immutable power, by waking and reposing alternately, revivi-

fies and destroys, in eternal succession, this whole assemblage of locomotive and immoveable creatures.'

It is then declared that there has been a long succession of *manwantaras*, or periods, each of the duration of many thousand ages, and—

'There are creations also, and destructions of worlds innumerable: the Being, supremely exalted, performs all this with as much ease as if in sport, again and again for the sake of conferring happiness *.'

The compilation of the ordinances of Menù was not all the work of one author nor of one period, and to this circumstance some of the remarkable inequalities of style and matter are probably attributable. There are many passages, however, wherein the attributes and acts of the 'Infinite and Incomprehensible Being' are spoken of with much grandeur of conception and sublimity of diction, as some of the passages above cited, though sufficiently mysterious, may serve to exemplify. There are at the same time such puerile conceits and monstrous absurdities in the same cosmogony, that some may impute to mere accident any slight approximation to truth, or apparent coincidence between the oriental dogmas and observed facts. This pretended revelation, however, was not purely an effort of the unassisted imagination, nor invented without regard to the opinions and observations of naturalists. There are introduced into the same chapter, certain astronomical theories, evidently derived from observation and reasoning. Thus, for instance, it is declared that, at the North Pole, the year was divided into a long day and night, and that their long day was the northern, and their night the southern course of the sun; and to the inhabitants of the moon, it is said, one day is equal in length to one month of mortals †. If such statements cannot be resolved into mere conjectures, we have no right to refer, to mere chance, the prevailing notion, that

* Institutes of Hindoo Law, or the Ordinances of Menù, from the Sanscrit, translated by Sir William Jones, 1796.

† Menù Inst., c. i. 66 and 67.

the earth and its inhabitants had formerly undergone a succession of revolutions and catastrophes, interrupted by long intervals of tranquillity.

Now there are two sources in which such a theory may have originated. The marks of former convulsions on every part of the surface of our planet are obvious and striking. The remains of marine animals imbedded in the solid strata are so abundant, that they may be expected to force themselves on the observation of every people who have made some progress in refinement; and especially where one class of men are expressly set apart from the rest for study and contemplation. If these appearances are once recognized, it seems natural that the mind should come to the conclusion, not only of mighty changes in past ages, but of alternate periods of repose and disorder—of repose when the fossil animals lived, grew, and multiplied—of disorder, when the strata wherein they were buried became transferred from the sea to the interior of continents, and entered into high mountain chains. Those modern writers, who are disposed to disparage the former intellectual advancement and civilization of eastern nations, might concede some foundation of observed facts for the curious theories now under consideration, without indulging in exaggerated opinions of the progress of science; especially as universal catastrophes of the world, and exterminations of organic beings, in the sense in which they were understood by the Brahmin, are untenable doctrines.

We know that the Egyptian priests were aware, not only that the soil beneath the plains of the Nile, but that also the hills bounding the great valley, contained marine shells; and it could hardly have escaped the observation of Eastern philosophers, that some soils were filled with fossil remains, since so many national works were executed on a magnificent scale by oriental monarchs in very remote eras. Great canals and tanks required extensive excavations; and we know that in more recent times (the fourteenth century of our era) the removal of soil necessary for such undertakings, brought to

light geological phenomena, which attracted the attention of a people less civilized than were many of the older nations of the East *.

But although we believe the Brahmins, like the priests of Egypt, to have been acquainted with the existence of fossil remains in the strata, it is probable that the doctrine of successive destructions and renovations of the world merely received corroboration from such proofs; and that it was originally handed down, like the religious dogmas of most nations, from a ruder state of society. The true source of the system must be sought for in the exaggerated traditions of those partial, but often dreadful catastrophes, which are sometimes occasioned by various combinations of natural causes. Floods and volcanic eruptions, the agency of water and fire, are the chief instruments of devastation on our globe. We shall point out in the sequel the extent of these calamities, recurring at distant intervals of time, in the present course of nature; and shall only observe here, that they are so peculiarly calculated to inspire a lasting terror, and are so often fatal in their consequences to great multitudes of people, that it scarcely requires the passion for the marvellous, so characteristic of rude and half-civilized nations, still less the exuberant imagination of eastern writers, to augment them into general cataclysms and conflagrations.

Humboldt relates the interesting fact, that after the annihilation of a large part of the inhabitants of Cumana, by an earthquake in 1766, a season of extraordinary fertility ensued,

* This circumstance is mentioned in a Persian MS. copy of the historian Ferishta, in the library of the East India Company, relating to the rise and progress of the Mahomedan Empire in India, and procured from the library of Tippoo Sultan in 1799; and has been recently referred to at some length by Dr. Buckland. —(Geol. Trans., 2d Series, vol. ii. part iii. p. 389.)—It is stated that, in the year 762 (or 1360 of our era), the king employed fifty thousand labourers in cutting through a mound, so as to form a junction between the rivers Selima and Sutluj, and in this mound were found the bones of elephants and men, some of them petrified, and some of them resembling bone. The gigantic dimensions attributed to the human bones show them to have belonged to some of the larger pachidermata.

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posed at some remote epoch to have set out. The duration of this great cycle was variously estimated. According to Orpheus, it was 120,000 years; according to others, 300,000; and by Cassander it was taken to be 360,000 years*.

We learn particularly from the Timœus of Plato, that the Egyptians believed the world to be subject to occasional conflagrations and deluges, whereby the gods arrested the career of human wickedness, and purified the earth from guilt. After each regeneration, mankind were in a state of virtue and happiness, from which they gradually degenerated again into vice and immorality. From this Egyptian doctrine, the poets derived the fable of the decline from the golden to the iron age. The sect of Stoics adopted most fully the system of catastrophes destined at certain intervals to destroy the world. These they taught were of two kinds—the Cataclysm, or destruction by deluge, which sweeps away the whole human race, and annihilates all the animal and vegetable productions of nature; and the Ecpyrosis, or conflagration, which dissolves the globe itself. From the Egyptians also they derived the doctrine of the gradual debasement of man from a state of innocence. Towards the termination of each era the gods could no longer bear with the wickedness of men, and a shock of the elements or a deluge overwhelmed them; after which calamity, Astrea again descended on the earth, to renew the golden age†.

The connexion between the doctrine of successive catastrophes and repeated deteriorations in the moral character of the human race, is more intimate and natural than might at first be imagined. For, in a rude state of society, all great calamities are regarded by the people, as judgments of God on the wickedness of man. Thus, in our own time, the priests persuaded a large part of the population of Chili, and perhaps believed themselves, that the great earthquake of 1822 was a sign of the wrath of heaven for the great political revolution just then consummated in South America. In like manner, in the account given to Solon by the Egyptian priests, of the sub-

* Prichard's Egypt. Mythol., p. 182. † Ibid., p. 193.

in consequence of the great rains which accompanied the subterranean convulsions. 'The Indians,' he says, 'celebrated, after the ideas of an antique superstition, by festivals and dancing, the destruction of the world and the approaching epoch of its regeneration *.'

The existence of such rites among the rude nations of South America is most important, for it shows what effects may be produced by great catastrophes of this nature, recurring at distant intervals of time, on the minds of a barbarous and uncultivated race. The superstitions of a savage tribe are transmitted through all the progressive stages of society, till they exert a powerful influence on the mind of the philosopher. He may find, in the monuments of former changes on the earth's surface, an apparent confirmation of tenets handed down through successive generations, from the rude hunter, whose terrified imagination drew a false picture of those awful visitations of floods and earthquakes, whereby the whole earth as known to him was simultaneously devastated.

Egyptian Cosmogony. Respecting the cosmogony of the Egyptian priests, we gather much information from writers of the Grecian sects, who borrowed almost all their tenets from Egypt, and amongst others that of the former successive destruction and renovation of the world †. We learn from Plutarch, that this was the theme of one of the hymns of Orpheus, so celebrated in the fabulous ages of Greece. It was brought by him from the banks of the Nile; and we even find in his verses, as in the Indian systems, a definite period assigned for the duration of each successive world ‡. The returns of great catastrophes were determined by the period of the Annus Magnus, or great year, a cycle composed of the revolutions of the sun, moon, and planets, and terminating when these return together to the same sign whence they were sup-

* Humboldt et Bonpland, Voy. Relat. Hist., vol. i. p. 30.

† Prichard's Egypt. Mythol., p. 177.

‡ Plut. de Defectu Oraculorum, cap. 12. Censorinus de Die Natali. See also Prichard's Egypt. Mythol., p. 182.

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mersion of the island of Atlantis under the waters of the ocean, after repeated shocks of an earthquake, we find that the event happened when Jupiter had seen the moral depravity of the inhabitants*. Now, when the notion had once gained ground, whether from causes before suggested or not, that the earth had been destroyed by several genèral catastrophes, it would next be inferred that the human race had been as often destroyed and renovated. And, since every extermination was assumed to be *penal*, it could only be reconciled with divine justice, by the supposition that man, at each successive creation, was regenerated in a state of purity and innocence.

A very large portion of Asia, inhabited by the earliest nations whose traditions have come down to us, has been always subject to tremendous earthquakes. Of the geographical boundaries of these, and their effects, we shall, in the proper place, have occasion to speak. Egypt has, for the most part, been exempt from this scourge, and the tradition of catastrophes in that country was perhaps derived from the East.

One extraordinary fiction of the Egyptian mythology was the supposed intervention of a masculo-feminine principle, to which was assigned the development of the embryo world, somewhat in the way of incubation. For the doctrine was, that when the first chaotic mass had been produced, in the form of an egg, by a self-dependent and eternal Being, it required the mysterious functions of this masculo-feminine demi-urgus to reduce the component elements into organized forms.

Although it is scarcely possible to recall to mind this conceit without smiling, it does not seem to differ essentially in principle from some cosmological notions of men of great genius and science in modern Europe. The Egyptian philosophers ventured on the perilous task of seeking out some analogy to the mode of operation employed by the Author of Nature in the first creation of organized beings, and they compared it to that which governs the birth of new individuals

* Plato's Timœus.

by generation. To suppose that some general rules might be observed in the first origin of created beings, or the first introduction of new species into our system, was not absurd, nor inconsistent with anything known to us in the economy of the universe. But the hypothesis, that there was any analogy between such laws, and those employed in the continual reproduction of species once created, was purely gratuitous. In like manner, it is not unreasonable nor derogatory to the attributes of Omnipotence, to imagine that some general laws may be observed in the creation of new worlds; and if man could witness the birth of such worlds, he might reason by induction upon the origin of his own. But in the absence of such data, an attempt has been made to fancy some analogy between the agents now employed to destroy, renovate, and perpetually vary the earth's surface, and those whereby the first chaotic mass was formed, and brought by supposed nascent energy from the embryo to the habitable state.

By how many shades the elaborate systems, constructed on these principles, may differ from the mysteries of the 'Mundane Egg' of Egyptian fable, we shall not inquire. It would, perhaps, be dangerous ground, and some of our contemporaries might not sit as patiently as the Athenian audience, when the fiction of the chaotic egg, engrafted by Orpheus upon their own mythology, was turned into ridicule by Aristophanes. That comedian introduced his birds singing, in a solemn hymn, 'How sable-plumaged Night conceived in the boundless bosom of Erebus, and laid an egg, from which, in the revolution of ages, sprung Love, resplendent with golden pinions. Love fecundated the dark-winged chaos, and gave origin to the race of birds*."

Pythagorean Doctrines. Pythagoras, who resided for more than twenty years in Egypt, and, according to Cicero, had visited the East, and conversed with the Persian philosophers, introduced into his own country, on his return, the doctrine of the gradual deterioration of the human race from an original

* Aristophanes' Birds, 694.

state of virtue and happiness; but if we are to judge of his theory concerning the destruction and renovation of the earth, from the sketch given by Ovid, we must concede it to have been far more philosophical than any known version of the cosmologies of Oriental or Egyptian sects. Although Pythagoras is introduced by the poet as delivering his doctrine in person, some of the illustrations are derived from natural events which happened after the death of the philosopher.

But notwithstanding these anachronisms, we may regard the account as a true picture of the tenets of the Pythagorean school in the Augustan age; and although perhaps partially modified, it must have contained the substance of the original scheme. Thus considered, it is extremely curious and instructive; for we here find a comprehensive and masterly summary of almost all the great causes of change now in activity on the globe, and these adduced in confirmation of a principle of perpetual and gradual revolution inherent in the nature of our terrestrial system. These doctrines, it is true, are not directly applied to the explanation of *geological* phenomena; or, in other words, no attempt is made to estimate what may have been, in past ages, or what may hereafter be, the aggregate amount of change brought about by such never-ending fluctuations. Had this been the case, we might have been called upon to admire so extraordinary an anticipation with no less interest than astronomers, when they endeavour to divine by what means the Samian philosopher came to the knowledge of the Copernican theory. Let us now examine the celebrated passages to which we have been adverting*:—

'Nothing perishes in this world; but things merely vary and change their form. To be born, means simply that a thing begins to be something different from what it was before; and dying, is ceasing to be the same thing. Yet, although nothing retains long the same image, the sum of the whole remains constant.' These general propositions are then confirmed by a series of examples, all derived from natural appearances,

* Ovid's Metamor., lib. 15.

except the first, which refers to the golden age giving place to the age of iron. The illustrations are thus consecutively adduced.

1. Solid land has been converted into sea.

2. Sea has been changed into land. Marine shells lie far distant from the deep, and the anchor has been found on the summit of hills.

3. Valleys have been excavated by running water, and floods have washed down hills into the sea *.

4. Marshes have become dry ground.

5. Dry lands have been changed into stagnant pools.

6. During earthquakes some springs have been closed up, and new ones have broken out. Rivers have deserted their channels, and have been re-born elsewhere; as the Erasinus in Greece, and Mysus in Asia.

7. The waters of some rivers, formerly sweet, have become bitter, as those of the Anigris in Greece, &c. †

8. Islands have become connected with the main land by the growth of deltas and new deposits, as in the case of Antissa joined to Lesbos, Pharos to Egypt, &c.

9. Peninsulas have been divided from the main land, and have become islands, as Leucadia; and according to tradition Sicily, the sea having carried away the isthmus.

10. Land has been submerged by earthquakes: the Grecian cities of Helice and Buris, for example, are to be seen under the sea, with their walls inclined.

11. Plains have been upheaved into hills by the confined air seeking vent, as at Træzen in the Peloponnese.

12. The temperature of some springs varies at different periods. The waters of others are inflammable ‡.

* Eluvie mons est deductus in æquor, v. 267. The meaning of this last verse is somewhat obscure, but taken with the context, may be supposed to allude to the abrading power of floods, torrents, and rivers.

† The impregnation from new mineral springs, caused by earthquakes in volcanic countries, is, perhaps, here alluded to.

‡ This is probably an allusion to the escape of inflammable gas, like that in the district of Baku, west of the Caspian; at Pietra-mala, in the Tuscan Apennines; and several other places.

13. There are streams which have a petrifying power, and convert the substances which they touch into marble.

14. Extraordinary medicinal and deleterious effects are produced by the water of different lakes and springs *.

15. Some rocks and islands, after floating, and having been subject to violent movements, have at length become stationary and immoveable, as Delos, and the Cyanean Isles †.

16. Volcanic vents shift their position; there was a time when Etna was not a burning mountain, and the time will come when it will cease to burn. Whether it be that some caverns become closed up by the movements of the earth, and others opened, or whether the fuel is finally exhausted, &c. &c.

The various causes of change in the inanimate world having been thus enumerated, the doctrine of equivocal generation is next propounded, as illustrating a corresponding perpetual flux in the animate creation ‡.

In the Egyptian and Eastern cosmogonies, and in the Greek version of them, no very definite meaning can, in general, be

* Many of those described seem fanciful fictions, like the virtues still so commonly attributed to mineral waters.

† Raspe, in a learned and judicious essay (De Novis Insulis, chap. 19), has made it appear extremely probable that all the traditions of certain islands in the Mediterranean having at some former time frequently shifted their positions, and at length become stationary, originated in the great change produced in their form by earthquakes and submarine eruptions, of which there have been modern examples in the new islands raised in the time of history. When the series of convulsions ended, the island was said to become fixed.

‡ It is not inconsistent with the Hindoo mythology to suppose that Pythagoras might have found in the East not only the system of universal and violent catastrophes and periods of repose in endless succession, but also that of periodical revolutions, effected by the continued agency of ordinary causes. For Brahma, Vishnu, and Siva, the first, second, and third persons of the Hindoo triad, severally represented the Creative, the Preserving, and the Destroying powers of the Deity. The co-existence of these three attributes, all in simultaneous operation, might well accord with the notion of perpetual but partial alterations finally bringing about a complete change. But the fiction expressed in the verses before quoted from Menù, of eternal vicissitudes in the vigils and slumbers of the Infinite Being, seems accommodated to the system of great general catastrophes followed by new creations and periods of repose.

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attached to the term 'destruction of the world,' for sometimes it would seem almost to imply the annihilation of our planetary system, and at others a mere revolution of the surface of the earth.

Opinions of Aristotle.—From the works now extant of Aristotle, and from the system of Pythagoras, as above exposed, we might certainly infer that these philosophers considered the agents of change now operating in Nature, as capable of bringing about in the lapse of ages a complete revolution; and the Stagyrite even considers occasional catastrophes, happening at distant intervals of time, as part of the regular and ordinary course of Nature. The deluge of Deucalion, he says, affected Greece only, and principally the part called Hellas, and it arose from great inundations of rivers during a rainy winter. But such extraordinary winters, he says, though after a certain period they return, do not always revisit the same places *.

Censorinus quotes it as Aristotle's opinion, that there were general inundations of the globe, and that they alternated with conflagrations, and that the flood constituted the winter of the great year, or astronomical cycle, while the conflagration, or destruction by fire, is the summer or period of greatest heat †. If this passage, as Lipsius supposes, be an amplification, by Censorinus, of what is written in 'the Meteorics,' it is a gross misrepresentation of the doctrine of the Stagyrite, for the general bearing of his reasoning in that treatise tends clearly in an opposite direction. He refers to many examples of changes now constantly going on, and insists emphatically on the great results which they must produce in the lapse of ages. He instances particular cases of lakes that had dried up, and deserts that had at length become watered by rivers and fertilized. He points to the growth of the Nilotic delta since the time of Homer, to the shallowing of the Palus Mæotis within sixty years from his own time, and although, in the same chapter, he says nothing of earthquakes, yet in others of the same

* Meteor. lib. i. cap. xii.

† De Die Nat.

treatise*, he shows himself not unacquainted with their effects. He alludes, for example, to the upheaving of one of the Eolian islands, previous to a volcanic eruption. 'The changes of the earth, he says, are so slow in comparison to the duration of our lives, that they are overlooked (λανθανει); and the migrations of people after great catastrophes, and their removal to other regions, cause the event to be forgotten †.'

When we consider the acquaintance displayed by Aristotle with the destroying and renovating powers of Nature in his various works, the introductory and concluding passages of the twelfth chapter of his 'Meteorics' are certainly very remarkable. In the first sentence he says, 'the distribution of land and sea in particular regions does not endure throughout all time, but it becomes sea in those parts where it was land, and again it becomes land where it was sea, and there is reason for thinking that these changes take place according to a certain system, and within a certain period.' The concluding observation is as follows: 'As time never fails, and the universe is eternal, neither the Tanais, nor the Nile, can have flowed for ever. The places where they rise were once dry, and there is a limit to their operations, but there is none to time. So also of all other rivers; they spring up and they perish; and the sea also continually deserts some lands and invades others. The same tracts, therefore, of the earth are not some always sea, and others always continents, but every thing changes in the course of time.'

It seems, then, that the Greeks had not only derived from preceding nations, but had also, in some slight degree, deduced from their own observations, the theory of great periodical revolutions in the inorganic world; there is, however, no ground for imagining that they contemplated former changes in the races of animals and plants. Even the fact, that marine remains were inclosed in solid rocks, although observed by many, and even made the groundwork of geological speculation, never stimulated the industry or guided the inquiries of naturalists.

* Lib. ii. cap. 14, 15, and 16. † Ibid.

It is not impossible that the theory of equivocal generation might have engendered some indifference on this subject, and that a belief in the spontaneous production of living beings from the earth, or corrupt matter, might have caused the organic world to appear so unstable and fluctuating, that phenomena indicative of former changes would not awaken intense curiosity. The Egyptians, it is true, had taught, and the Stoics had repeated, that the earth had once given birth to some monstrous animals, which existed no longer; but the prevailing opinion seems to have been, that after each great catastrophe the same species of animals were created over again. This tenet is implied in a passage of Seneca, where, speaking of a future deluge, he says, 'Every animal shall be generated anew, and men free from guilt shall be given to the earth *.'

An old Arabian version of the doctrine of the successive revolutions of the globe, translated by Abraham Ecchellensis †, seems to form a singular exception to the general rule, for here we find the idea of different genera and species having been created. The Gerbanites, a sect of astronomers who flourished some centuries before the Christian era, taught as follows:—'That after every period of thirty-six thousand years, there were produced twenty-five pair of *every* species of animals, male and female, from whom animals might be propagated and inhabit this lower world. But when a circulation of the heavenly orbs was completed, which is finished in that space of years, *other genera and species* of animals are propagated, as also of plants and other things, and the first order is destroyed, and so it goes on for ever and ever ‡.'

* Omne ex integro animal generabitur, dabiturque terris homo inscius scelerum. Quest. Nat. iii. c. 29.

† This author was Regius Professor of Syriac and Arabic at Paris, where, in 1685, he published a Latin Translation of many Arabian MSS. on different departments of philosophy. This work has always been considered of high authority.

‡ Gerbanitæ docebant singulos triginta sex mille annos quadringentos, viginti quinque bina ex singulis animalium speciebus produci, marem scilicet ac feminam, ex quibus animalia propagantur, huncque inferiorem incolunt orbem. Absolutâ

Theory of Strabo.—As we learn much of the tenets of the Egyptian and Oriental schools in the writings of the Greeks, so many speculations of the early Greek authors are made known to us in the works of the Augustan and later ages. Strabo, in particular, enters largely, in the Second Book of his Geography, into the opinions of Eratosthenes and other Greeks on one of the most difficult problems in geology, *viz.*, by what causes marine shells came to be plentifully buried in the earth at such great elevations and distances from the sea.

He notices, amongst others, the explanation of Xanthus the Lydian, who said that the seas had once been more extensive, and that they had afterwards been partially dried up, as in his own time many lakes, rivers, and wells in Asia had failed during a season of drought. Treating this conjecture with merited disregard, Strabo passes on to the hypothesis of Strato, the natural philosopher, who had observed that the quantity of mud brought down by rivers into the Euxine was so great, that its bed must be gradually raised, while the rivers still continued to pour in an undiminished quantity of water. He therefore conceived that, originally, when the Euxine was an inland sea, its level had by this means become so much elevated that it burst its barrier near Byzantium, and formed a communication with the Propontis, and this partial drainage had already, he supposed, converted the left side into marshy ground, and that, at last, the whole would be choked up with soil. So, it was argued, the Mediterranean had once opened a passage for itself by the Columns of Hercules into the Atlan-

autem cœlestium orbium circulatione, quæ illo annorum conficitur spatio, iterum alia producuntur animalium genera et species, quemadmodum et plantarum aliarumque rerum, et primus destruitur ordo, sicque in infinitum producitur.—Histor. Orient. Suppl. per Abrahamum Ecchellensum, Syrum Maronitam, cap. 7 et 8. ad calcem Chronici Oriental. Parisiis, e Typ. regia 1685. fol.

Fortis fell into a singular mistake in rendering this passage, imagining that the number twenty-five referred, not to the pairs of every animal created, but to the number of new species created at one time; and hence the doctrine of the Arabian sect appeared to coincide somewhat with his own views; and to be consistent with his hypothesis, that man and some species of animals and plants are more modern than others.—Fortis, Mem. sur l'Hist. Nat. de l'Italie, vol. i. p. 202.

tic, and perhaps the abundance of sea-shells in Africa, near the Temple of Jupiter Ammon, might also be the deposit of some former inland sea, which had at length forced a passage and escaped.

But Strabo rejects this theory as insufficient to account for all the phenomena, and he proposes one of his own, the profoundness of which modern geologists are only beginning to appreciate. 'It is not,' he says, 'because the lands covered by seas were originally at different altitudes, that the waters have risen, or subsided, or receded from some parts and inundated others. But the reason is, that the same land is sometimes raised up and sometimes depressed, and the sea also is simultaneously raised and depressed, so that it either overflows or returns into its own place again. We must therefore ascribe the cause to the ground, either to that ground which is under the sea, or to that which becomes flooded by it, but rather to that which lies beneath the sea, for this is more moveable, and, on account of its humidity, can be altered with great celerity*. *It is proper,*' he observes in continuation, '*to derive our explanations from things which are obvious, and in some measure of daily occurrence, such as deluges, earthquakes, volcanic eruptions, and sudden swellings of the land beneath the sea;* for the last raise up the sea also, and when the same lands subside again, they occasion the sea to be let down. And it is not merely the small, but the large islands also, and not merely the islands, but the continents, which can be lifted up together with the sea; and both large and small tracts may subside, for habitations and cities, like Bure, Bizona, and many others, have been engulphed by earthquakes.'

In another place, this learned geographer, in alluding to the

* 'Quod enim hoc attollitur aut subsidit, et vel inundat quædam loca, vel ab iis recedit, ejus rei causa non est, quod alia aliis sola humiliora sint aut altiora; sed quod idem solum modò attollitur modò deprimitur, simulque etiam modò attollitur modò deprimitur mare: itaque vel exundat vel in suum redit locum.'

Posteà, p. 88. 'Restat, ut causam adscribamus solo, sive quod mari subest sive quod inundatur; potiùs tamen ei quod mari subest. Hoc enim multò es mobilius et quod ob humiditatem celeriùs mutari possit.'—Strabo, lib. ii.

tradition that Sicily had been separated by a convulsion from Italy, remarks, that at present the land near the sea in those parts was rarely shaken by earthquakes, since there were now open orifices whereby fire and ignited matters and waters escaped; but formerly, when the volcanos of Etna, the Lipari Islands, Ischia, and others, were closed up, the imprisoned fire and wind might have produced far more vehement movements *. The doctrine, therefore, that volcanos are safety-valves, and that the subterranean convulsions are probably most violent when first the volcanic energy shifts itself to a new quarter, is not modern.

We learn from a passage in Strabo †, that it was a dogma of the Gaulish Druids that the universe was immortal, but destined to survive catastrophes both of fire and water. That this doctrine was communicated to them from the East, with much of their learning, cannot be doubted. Cæsar ‡, it will be remembered, says that they made use of Greek letters in arithmetical computations.

Pliny had no theoretical opinions of his own concerning changes of the earth's surface; and in this department, as in others, he restricted himself to the task of a compiler, without reasoning on the facts stated by him, or attempting to digest them into regular order. But his enumeration of the new islands which had been formed in the Mediterranean, and of other convulsions, shews that the ancients had not been inattentive observers of the changes which had taken place on the earth within the memory of man.

We shall now conclude our remarks on the opinions entertained before the Christian era, concerning the past revolutions of our globe. No particular investigations appear to have been made for the express purpose of interpreting the monuments left by nature of ancient changes, but they were too obvious to be entirely disregarded; and the observation of the present course of nature presented too many proofs of alterations continually in progress on the earth to allow philosophers to believe

* Strabo, lib. vi. p. 396. † Book iv. ‡ l. vi. ch. xiii.

that nature was in a state of rest, or that the surface had remained, and would continue to remain, unaltered. But they had never compared attentively the results of the destroying and reproductive operations of modern times with those of remote eras, nor had they ever entertained so much as a conjecture concerning the comparative antiquity of the human race, or of living species of animals and plants, with those belonging to former conditions of the organic world. They had studied the movements and positions of the heavenly bodies with laborious industry, and made some progress in investigating the animal, vegetable, and mineral kingdoms; but the ancient history of the globe was to them a sealed book, and, although written in characters of the most striking and imposing kind, they were unconscious even of its existence.

CHAPTER III.

Arabian writers of the tenth century—Persecution of Omar—Cosmogony of the Koran—Early Italian writers—Fracastoro—Controversy as to the real nature of organized fossils—Fossil shells attributed to the Mosaic deluge—Palissy—Steno—Scilla—Quirini—Boyle—Plot—Hooke's Theory of Elevation by earthquakes—His speculations on lost species of animals—Ray—Physico-theological writers—Woodward's Diluvial Theory—Burnet—Whiston—Hutchinson—Leibnitz—Vallisneri—Lazzaro Moro—Generelli—Buffon—His theory condemned by the Sorbonne as unorthodox—Buffon's declaration—Targioni—Arduino—Michell—Catcott—Raspe—Fortis—Testa—Whitehurst—Pallas—Saussure.

Arabian writers.—After the decline of the Roman empire, the cultivation of physical science was first revived with some success by the Saracens, about the middle of the eighth century of our era. The works of the most eminent classic writers were purchased at great expense from the Christians, and translated into Arabic; and Al Mamûn, son of the famous Harûn-al-Rashid, the contemporary of Charlemagne, received with marks of distinction, at his court at Bagdad, astronomers and men of learning from different countries. This caliph, and some of his successors, encountered much opposition and jealousy from the doctors of the Mahomedan law, who wished the Moslems to confine their studies to the Koran, dreading the effects of the diffusion of a taste for the physical sciences *.

Omar—Cosmogony of the Koran.—Almost all the works of the early Arabian writers are lost. Amongst those of the tenth century, of which fragments are now extant, is a system of mineralogy by Avicenna, a physician, in whose arrangement there is considerable merit. In the same century also, Omar, surnamed 'El Aalem,' or 'the Learned,' wrote a work on 'the Retreat of the Sea.' It appears that on comparing the charts

* Mod. Univ. Hist. vol. ii. chap. iv. section iii.

of his own time with those made by the Indian and Persian astronomers two thousand years before, he had satisfied himself that important changes had taken place since the times of history in the form of the coasts of Asia, and that the extension of the sea had been greater at some former periods. He was confirmed in this opinion by the numerous salt springs and marshes in the interior of Asia,—a phenomenon from which Pallas, in more recent times, has drawn the same inference.

Von Hoff has suggested, with great probability, that the changes in the level of the Caspian (some of which there is reason to believe have happened within the historical era), and the geological appearances in that district, indicating the desertion by that sea of its ancient bed, had probably led Omar to his theory of a general subsidence. But whatever may have been the proofs relied on, his system was declared contradictory to certain passages in the Koran, and he was called upon publicly to recant his errors; to avoid which persecution he went into voluntary banishment from Samarkand*.

The cosmological opinions expressed in the Koran are few, and merely introduced incidentally; so that it is not easy to understand how they could have interfered so seriously with free discussion on the former changes of the globe. The Prophet declared that the earth was created in two days, and the mountains were then placed on it; and during these, and two additional days, the inhabitants of the earth were formed; and

* Von Hoff, Geschichte der Veränderungen der Erdoberfläche, vol. i. p. 406, who cites Delisle, bey Hissmann Welt-und Völkergeschichte. Alte Gesch. 1ter Theil. s. 234.—The Arabian persecutions for heretical dogmas in theology were often very sanguinary. In the same ages wherein learning was most in esteem, the Mahometans were divided into two sects, one of whom maintained that the Koran was increate, and had subsisted in the very essence of God from all eternity; and the other the Motazalites, who, admitting that the Koran was instituted by God, conceived it to have been first made when revealed to the Prophet at Mecca, and accused their opponents of believing in two eternal beings. The opinions of each of these sects were taken up by different caliphs in succession, and the followers of each sometimes submitted to be beheaded, or flogged till at the point of death, rather than renounce their creed.—Mod. Univ. Hist. vol. ii. ch. iv.

in two more the seven heavens*. There is no more detail of circumstances; and the deluge, which is also mentioned, is discussed with equal brevity. The waters are represented to have poured out of an oven; a strange fable, said to be borrowed from the Persian Magi, who represented them as issuing from the oven of an old woman †. All men were drowned, save Noah and his family; and then God said, 'O earth, swallow up thy waters; and thou, O heaven, withhold thy rain;' and immediately the waters abated ‡.

We may suppose Omar to have represented the desertion of the land by the sea to have been gradual, and that his hypothesis required a greater lapse of ages than was consistent with Moslem orthodoxy; for it is to be inferred from the Koran, that man and this planet were created at the same time; and although Mahomet did not limit expressly the antiquity of the human race, yet he gave an implied sanction to the Mosaic chronology by the veneration expressed by him for the Hebrew Patriarchs §.

Early Italian writers—Fracastoro, 1517.—We must now pass over an interval of five centuries, wherein darkness enveloped almost every department of science, and buried in profound oblivion all prior investigations into the earth's history and structure. It was not till the earlier part of the sixteenth century that geological phenomena began to attract the attention of the Christian nations. At that period a very animated controversy sprung up in Italy, concerning the true nature and origin of marine shells, and other organized fossils, found abundantly in the strata of the peninsula ||. The excavations made in 1517, for repairing the city of Verona, brought

* Koran, chap. xli.

† Sale's Koran, chap. xi., see note. ‡ Ibid.

§ Kossa, appointed master to the Caliph Al Mamûd, was author of a book, entitled, 'The history of the Patriarchs and Prophets, *from the Creation of the World*.'—Mod. Univ. Hist., vol. ii. chap. iv.

|| See Brocchi's Discourse on the Progress of the Study of Fossil Conchology in Italy, where some of the following notices on Italian writers will be found more at large.

to light a multitude of curious petrifactions, and furnished matter for speculation to different authors, and among the rest to Fracastoro *, who declared his opinion, that fossil shells had all belonged to living animals, which had formerly lived and multiplied, where their exuviæ are now found. He exposed the absurdity of having recourse to a certain 'plastic force,' which it was said had power to fashion stones into organic forms; and, with no less cogent arguments, demonstrated the futility of attributing the situation of the shells in question to the Mosaic deluge, a theory obstinately defended by some. That inundation, he observed, was too transient, it consisted principally of fluviatile waters; and if it had transported shells to great distances, must have strewed them over the surface, not buried them at vast depths in the interior of mountains. His clear exposition of the evidence would have terminated the discussion for ever, if the passions of mankind had not been enlisted in the dispute; and even though doubts should for a time have remained in some minds, they would speedily have been removed by the fresh information obtained almost immediately afterwards, respecting the structure of fossil remains, and of their living analogues.

But the clear and philosophical views of Fracastoro were disregarded, and the talent and argumentative powers of the learned were doomed for three centuries to be wasted in the discussion of these two simple and preliminary questions: first, whether fossil remains had ever belonged to living creatures; and, secondly, whether, if this be admitted, all the phenomena could be explained by the Noachian deluge. It had been the consistent belief of the Christian world, down to the period now under consideration, that the origin of this planet was not more remote than a few thousand years; and that since the creation the deluge was the only great catastrophe by which considerable change had been wrought on the earth's surface. On the other hand, the opinion was scarcely less general, that the final dissolution of our system was an event to be looked

* Museum Calceol.

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for at no distant period. The era, it is true, of the expected millennium had passed away; and for five hundred years after the fatal hour, when the annihilation of the planet had been looked for, the monks remained in undisturbed enjoyment of rich grants of land bequeathed to them by pious donors, who, in the preamble of deeds beginning 'appropinquante mundi termino'——'appropinquante magno judicii die,' left lasting monuments of the popular delusion *.

But although in the sixteenth century it had become necessary to interpret the prophecies more liberally, and to assign a more distant date to the future conflagration of the world, we find, in the speculations of the early geologists, perpetual allusion to such an approaching catastrophe; while in all that regarded the antiquity of the earth, no modification whatever of the opinions of the dark ages had been effected. Considerable alarm was at first excited when the attempt was made to invalidate, by physical proofs, an article of faith so generally received; but there was sufficient spirit of toleration and candour amongst the Italian ecclesiastics, to allow the subject to be canvassed with much freedom. They entered warmly themselves into the controversy, often favouring different sides of the question; and however much we may deplore the loss of time and labour devoted to the defence of untenable positions, it must be conceded, that they displayed far less polemic bitterness than certain writers who followed them 'beyond the Alps,' two centuries and a half later.

CONTROVERSY AS TO THE REAL NATURE OF FOSSIL ORGANIC REMAINS.

Mattioli—Falloppio.—The system of scholastic disputations encouraged in the Universities of the middle ages had unfortunately trained men to habits of indefinite argumentation, and they often preferred absurd and extravagant propositions,

* In the monasteries of Sicily, in particular, the title-deeds of many valuable grants of land are headed by such preambles, composed by the testators about the period when the good King Roger was expelling the Saracens from that island.

because greater skill was required to maintain them; the end and object of such intellectual combats being victory and not truth. No theory could be so far-fetched or fantastical as not to attract some followers, provided it fell in with popular notions; and as cosmologists were not at all restricted, in building their systems, to the agency of known causes, the opponents of Fracastoro met his arguments by feigning imaginary causes, which differed from each other rather in name than in substance. Andrea Mattioli, for instance, an eminent botanist, the illustrator of Dioscorides, embraced the notion of Agricola, a German miner, that a certain 'materia pinguis' or 'fatty matter,' set into fermentation by heat, gave birth to fossil organic shapes. Yet Mattioli had come to the conclusion, from his own observations, that porous bodies, such as bones and shells, might be converted into stone, as being permeable to what he termed the 'lapidifying juice.' In like manner, Falloppio of Padua conceived that petrified shells had been generated by fermentation in the spots where they were found, or that they had in some cases acquired their form from 'the tumultuous movements of terrestrial exhalations.' Although a celebrated professor of anatomy, he taught that certain tusks of elephants dug up in his time at Puglia were mere earthy concretions, and, consistently with these principles, he even went so far as to consider it not improbable, that the vases of Monte Testaceo at Rome were natural impressions stamped in the soil*. In the same spirit, Mercati, who published, in 1574, faithful figures of the fossil shells preserved by Pope Sextus V. in the Museum of the Vatican, expressed an opinion that they were mere stones, which had assumed their peculiar configuration from the influence of the heavenly bodies; and Olivi of Cremona, who described the fossil remains of a rich Museum at Verona, was satisfied with considering them mere 'sports of nature.'

Cardano, 1552.—The title of a work of Cardano's, published in 1552, 'De Subtilitate,' (corresponding to what would

* De Fossilib., pp. 109 and 176.

now be called Transcendental Philosophy,) would lead us to expect, in the chapter on minerals, many far-fetched theories characteristic of that age; but, when treating of petrified shells, he decided that they clearly indicated the former sojourn of the sea upon the mountains *.

Some of the fanciful notions of those times were deemed less unreasonable, as being somewhat in harmony with the Aristotelian theory of spontaneous generation, then taught in all the schools. For men who had been instructed in early youth, that a large proportion of living animals and plants were formed from the fortuitous concourse of atoms, or had sprung from the corruption of organic matter, might easily persuade themselves, that organic shapes, often imperfectly preserved in the interior of solid rocks, owed their existence to causes equally obscure and mysterious.

Cesalpino—Majoli, 1597.—But there were not wanting some, who at the close of this century expressed more sound and sober opinions. Cesalpino, a celebrated botanist, conceived that fossil shells had been left on the land by the retiring sea, and had concreted into stone during the consolidation of the soil †; and in the following year (1597), Simeone Majoli ‡ went still farther, and, coinciding for the most part with the views of Cesalpino, suggested that the shells and submarine matter of the Veronese, and other districts, might have been cast up, upon the land, by volcanic explosions, like those which gave rise, in 1538, to Monte Nuovo, near Puzzuoli.—This hint was the first imperfect attempt to connect the position of fossil shells with the agency of volcanos, a system afterwards more fully developed by Hooke, Lazzaro Moro, Hutton, and other writers.

Two years afterwards, Imperati advocated the animal origin of fossilized shells, yet admitted that stones could vegetate by force of 'an internal principle;' and, as evidence of this, he

* Brocchi, Con. Foss. Subap. Disc. sui Prog., vol. i. p. 5.

† De Metallicis.

‡ Dies Caniculares.

referred to the teeth of fish, and spines of echini found petrified *.

Palissy, 1580.—Palissy, a French writer on 'the Origin of Springs from Rain-water' and of other scientific works, undertook, in 1580, to combat the notions of many of his contemporaries in Italy, that petrified shells had all been deposited by the universal deluge. 'He was the first,' said Fontenelle, when, in the French Academy, he pronounced his eulogy nearly a century and a half later, 'who dared assert' in Paris, that fossil remains of testacea and fish had once belonged to marine animals.

Fabio Colonna.—To enumerate the multitude of Italian writers, who advanced various hypotheses, all equally fantastical, in the early part of the seventeeth century, would be unprofitably tedious, but Fabio Colonna deserves to be distinguished; for, although he gave way to the dogma, that all fossil remains were to be referred to the Noachian deluge, he resisted the absurd theory of Stelluti, who taught that fossil wood and ammonites were mere clay, altered into such forms by sulphureous waters and subterranean heat; and he pointed out the different states of shells buried in the strata, distinguishing between, first, the mere mould or impression; secondly, the cast or nucleus; and thirdly, the remains of the shell itself. He had also the merit of being the first to point out, that some of the fossils had belonged to marine, and some to terrestrial testacea †.

Steno, 1669.—But the most remarkable work of that period was published by Steno, a Dane, once professor of anatomy at Padua, and who afterwards resided many years at the court of the Grand Duke of Tuscany. The treatise bears the quaint title of 'De Solido intra Solidum contento naturaliter, (1669,)' by which the author intended to express 'On Gems, Crystals, and organic Petrifactions inclosed within solid Rocks.' This work attests the priority of the Italian school in geological research; exemplifying at the same time the powerful obstacles

* Storia Naturale. † Osserv. sugli Animali aquat. e terrest. 1626.

opposed, in that age, to the general reception of enlarged views in the science. Steno had compared the fossil shells with their recent analogues, and traced the various gradations from the state of mere calcination, when their natural gluten only was lost, to the perfect substitution of stony matter. He demonstrated that many fossil teeth found in Tuscany belonged to a species of shark; and he dissected, for the purpose of comparison, one of these fish recently taken from the Mediterranean. That the remains of shells and marine animals found petrified were not of animal origin was still a favourite dogma of many, who were unwilling to believe that the earth could have been inhabited by living beings long before many of the mountains were formed.

By way of compromise, as it were, for dissenting from this opinion, Steno conceded, as Fabio Colonna had done before him, that all marine fossils might have been transported into their present situation at the time of the Noachian deluge. He maintained that fossil vegetables had been once living plants, and he hinted that they might, in some instances, indicate the distinction between fluviatile and marine deposits. He also inferred that the present mountains had not existed ever since the origin of things, suggesting that many strata of submarine origin had been accumulated in the interval between the creation and deluge. Here he displayed his great anxiety to reconcile his theory with the Scriptures; for he at the same time advanced an opinion, which does not seem very consistent with such a doctrine, *viz.* that there was a wide distinction between the shelly, and nearly horizontal beds at the foot of the Apennines, and the older mountains of highly inclined stratification. Both, he observed, were of sedimentary origin; and a considerable interval of time must have separated their formation. Tuscany, according to him, had successively passed *through six different states;* and to explain these mighty changes, he called in the agency of inundations, earthquakes, and subterranean fires.

His generalizations were for the most part comprehensive

and just; but such was his awe of popular prejudice, that he only ventured to throw them out as mere conjectures, and the timid reserve of his expressions must have raised doubts as to his own confidence in his opinions, and deprived them of some of the authority due to them.

Scilla, 1670.—Scilla, a Sicilian painter, published, in 1670, a work on the fossils of Calabria, illustrated by good engravings. This was written in Latin, with great spirit and elegance, and it proves the continued ascendency of dogmas often refuted; for we find the wit and eloquence of the author chiefly directed against the obstinate incredulity of naturalists, as to the organic nature of fossil shells *. Like many eminent naturalists of his day, Scilla gave way to the popular persuasion, that all fossil shells were the effects and proofs of the Mosaic deluge. It may be doubted whether he was perfectly sincere, and some of his contemporaries who took the same course were certainly not so. But so eager were they to root out what they justly considered an absurd prejudice respecting the nature of organized fossils, that they seem to have been ready to make any concessions, in order to establish this preliminary point. Such a compromising policy was short-sighted, since it was to little purpose that the nature of the documents should at length be correctly understood, if men were to be prevented from deducing fair conclusions from them.

Diluvial Theory.—The theologians who now entered the field in Italy, Germany, France and England, were innumerable; and henceforward, they who refused to subscribe to the position, that all marine organic remains were proofs of the Mosaic deluge, were exposed to the imputation of disbelieving the whole of the sacred writings. Scarcely any step had been made in approximating to sound theories since the time of

* Scilla quotes the remark of Cicero on the story that a stone in Chios had been cleft open, and presented the head of Paniscus in relief—'I believe,' said the orator, 'that the figure bore some resemblance to Paniscus, but not such that you would have deemed it sculptured by Scopas, for chance never perfectly imitates the truth.'

Fracastoro, more than a hundred years having been lost, in writing down the dogma that organized fossils were mere sports of nature. An additional period of a century and a half was now destined to be consumed in exploding the hypothesis, that organized fossils had all been buried in the solid strata by the Noachian flood. Never did a theoretical fallacy, in any branch of science, interfere more seriously with accurate observation and the systematic classification of facts. In recent times, we may attribute our rapid progress chiefly to the careful determination of the order of succession in mineral masses, by means of their different organic contents, and their regular superposition. But the old diluvialists were induced by their system to confound all the groups of strata together instead of discriminating,—to refer all appearances to one cause and to one brief period, not to a variety of causes acting throughout a long succession of epochs. They saw the phenomena only as they desired to see them, sometimes misrepresenting facts, and at other times deducing false conclusions from correct data. Under the influence of such prejudices, three centuries were of as little avail, as a few years in our own times, when we are no longer required to propel the vessel against the force of an adverse current.

It may be well to forewarn our readers, that in tracing the history of geology from the close of the seventeenth to the end of the eighteenth century, they must expect to be occupied with accounts of the retardation, as well as of the advance of the science. It will be our irksome task to point out the frequent revival of exploded errors, and the relapse from sound to the most absurd opinions. It will be necessary to dwell on futile reasoning and visionary hypothesis, because the most extravagant systems were often invented or controverted by men of acknowledged talent. A sketch of the progress of Geology is the history of a constant and violent struggle between new opinions and ancient doctrines, sanctioned by the implicit faith of many generations, and supposed to rest on scriptural authority. The inquiry, therefore, although highly interesting to

one who studies the philosophy of the human mind, is singularly barren of instruction to him who searches for truths in physical science.

Quirini, 1676.—Quirini, in 1676*, contended, in opposition to Scilla, that the diluvian waters could not have conveyed heavy bodies to the summit of mountains, since the agitation of the sea never (as Boyle had demonstrated) extended to great depths†, and still less could the testacea, as some pretended, have lived in these diluvian waters, for 'the duration of the flood was brief, and *the heavy rains must have destroyed the saltness of the sea!*' He was the first writer who ventured to maintain that the universality of the Noachian cataclysm ought not to be insisted upon. As to the nature of petrified shells, he conceived that as earthy particles united in the sea to form the shells of mollusca, the same crystallizing process might be effected on the land, and that, in the latter case, the germs of the animals might have been disseminated through the substance of the rocks, and afterwards developed by virtue of humidity. Visionary as was this doctrine, it gained many proselytes even amongst the more sober reasoners of Italy and Germany, for it conceded both that fossil bodies were organic, and that the diluvial theory could not account for them.

Plot—Lister, 1678.—In the mean time, the doctrine that fossil shells had never belonged to real animals, maintained its ground in England, where the agitation of the question began at a much later period. Dr. Plot, in his 'Natural History of Oxfordshire,' (1677,) attributed to a 'plastic virtue

* De Testaceis fossilibus Mus. Septaliani.

† The opinions of Boyle, alluded to by Quirini, were published a few years before, in a short article entitled 'On the bottom of the Sea.' From observations collected from the divers of the pearl fishery, Boyle inferred that when the waves were six or seven feet high above the surface of the water, there were no signs of agitation at the depth of fifteen fathoms; and that even during heavy gales of wind, the motion of the water was exceedingly diminished at the depth of twelve or fifteen feet. He had also learnt from some of his informants, that there were currents running in opposite directions at different depths.—Boyle's Works, vol. iii. p. 110. London, 1744.

latent in the earth' the origin of fossil shells and fishes; and Lister, to his accurate account of British shells, in 1678, added the fossil species, under the appellation of *turbinated and bivalve stones.* 'Either,' said he, 'these were terriginous, or, if otherwise, the animals they so exactly represent *have become extinct.*' This writer appears to have been the first who was aware of the continuity over large districts of the principal groups of strata in the British series, and who proposed the construction of regular geological maps*.

Hooke, 1688.—The 'Posthumous Works of Robert Hooke, M.D.,' well known as a great mathematician and natural philosopher, appeared in 1705, containing, 'A Discourse of Earthquakes,' which, we are informed by his editor, was written in 1668, but revised at subsequent periods†. Hooke frequently refers to the best Italian and English authors who wrote before his time on geological subjects; but there are no passages in his works implying that he participated in the enlarged views of Steno and Lister, or of his contemporary, Woodward, in regard to the geographical extent of certain groups of strata. His treatise, however, is the most philosophical production of that age, in regard to the causes of former changes in the organic and inorganic kingdoms of nature.

'However trivial a thing,' he says, 'a rotten shell may appear to some, yet these monuments of nature are more certain tokens of antiquity than coins or medals, since the best of those may be counterfeited or made by art and design, as may also books, manuscripts, and inscriptions, as all the learned are now sufficiently satisfied has often been actually practised,' &c.; 'and though it must be granted that it is very difficult to read them (the records of nature) and *to raise a chronology out of them,* and to state the intervals of the time wherein such or

* See Mr. Conybeare's excellent Introduction to the 'Outlines of the Geology of England and Wales,' p. 12.

† Between the year 1688 and his death, in 1703, he read several memoirs to the Royal Society, and delivered lectures on various subjects, relating to fossil remains and the effects of earthquakes.

such catastrophes and mutations have happened, yet it is not impossible *.'

His theory of the extinction of Species.—Respecting the extinction of species, Hooke was aware that the fossil ammonites, nautili, and many other shells and fossil skeletons found in England, were of different species from any then known; but he doubted whether the species had become extinct, observing that the knowledge of naturalists of all the marine species, especially those inhabiting the deep sea, was very deficient. In some parts of his writings, however, he leans to the opinion that species had been lost; and, in speculating on this subject, he even suggests that there might be some connexion between the disappearance of certain kinds of animals and plants, and the changes wrought by earthquakes in former ages. Some species, he observes with great sagacity, are '*peculiar to certain places*, and not to be found elsewhere. If, then, such a place had been swallowed up, it is not improbable but that those animate beings may have been destroyed with it; and this may be true both of aërial and aquatic animals: for those animated bodies, whether vegetables or animals, which were naturally nourished or refreshed by the air, would be destroyed by the water †,' &c. Turtles, he adds, and such large ammonites as are found in Portland, seem to have been the productions of the seas of hotter countries, and *it is necessary to suppose that England once lay under the sea within the torrid zone!* To explain this and similar phenomena, he indulges in a variety of speculations concerning changes in the position of the axis of the earth's rotation, a shifting of the earth's centre of gravity, '*analogous to the revolutions of the magnetic pole,*' &c. None of these conjectures, however, are proposed dogmatically, but rather in the hope of promoting fresh inquiries and experiments.

In opposition to the prejudices of his age, we find him arguing that nature had not formed fossil bodies 'for no other end

* Posth. Works, Lecture Feb. 29, 1688.

† Posth. Works, p. 327.

than to play the mimic in the mineral kingdom'—that figured stones were 'really the several bodies they represent, or the mouldings of them petrified,' and 'not, as some have imagined, a "lusus naturæ," sporting herself in the needless formation of useless beings *.'

It was objected to Hooke, that his doctrine of the extinction of species derogated from the wisdom and power of the Omnipotent Creator; but he answered, that, as individuals die, there may be some termination to the duration of a species; and his opinions, he declared, were not repugnant to Holy Writ: for the Scriptures taught that our system was degenerating, and tending to its final dissolution; 'and as, when that shall happen, all the species will be lost, why not some at one time and some at another † ?'

His theory of the effects of earthquakes.—But his principal object was to account for the manner in which shells had been conveyed into the higher parts of 'the Alps, Apennines, and Pyrenean hills, and the interior of continents in general.' These and other appearances, he said, might have been brought about by earthquakes, 'which have turned plains into mountains, and mountains into plains, seas into land, and land into seas, made rivers where there were none before, and swallowed up

* Posth. Works, Lecture Feb. 15, 1688. Hooke explained, with considerable clearness, the different modes wherein organic substances may become lapidified; and, among other illustrations, he mentions some silicified palm-wood brought from Africa, on which M. de la Hire had read a Memoir to the Royal Academy of France, (June, 1692,) wherein he had pointed out not only the tubes running the length of the trunk, but the roots at one extremity. De la Hire, says Hooke, also treated of certain trees found petrified in 'the river that passes by Bakan, in the kingdom of *Ava*, and which has for the space of ten leagues the virtue of petrifying wood.' It is an interesting fact, that the silicified wood of the Irawadi should have attracted attention more than one hundred years ago. Remarkable discoveries have been recently made there of fossil animals and vegetables by Mr. Crawfurd and Dr. Wallich.—See Geol. Trans., vol. ii. part iii. p. 377, Second Series. De la Hire cites Father Duchatz, in the second volume of 'Observations made in the Indies by the Jesuits.'

† Posth. Works, Lecture May 29, 1689.

others that formerly were, &c. &c.; and which, since the creation of the world, have wrought many great changes on the superficial parts of the earth, and have been the instruments of placing shells, bones, plants, fishes, and the like, in those places, where, with much astonishment, we find them *.' This doctrine, it is true, had been laid down in terms almost equally explicit by Strabo, to explain the occurrence of fossil shells in the interior of continents, and to that geographer, and other writers of antiquity, Hooke frequently refers; but the revival and development of the system was an important step in the progress of modern science.

Hooke enumerated all the examples known to him of subterranean disturbance, from 'the sad catastrophe of Sodom and Gomorrah' down to the Chilian earthquake of 1646. The elevating of the bottom of the sea, the sinking and submersion of the land, and most of the inequalities of the earth's surface, might, he said, be accounted for by the agency of these subterranean causes. He mentions that the coast near Naples was raised during the eruption of Monte Nuovo; and that, in 1591, land rose in the island of St. Michael, during an eruption; and although it would be more difficult, he says, to prove, he does not doubt but that there had been *as many earthquakes in the parts of the earth under the ocean, as in the parts of the dry land;* in confirmation of which he mentions the immeasurable depth of the sea near some volcanos. To attest the extent of simultaneous subterranean movements, he refers to an earthquake in the West Indies, in 1690, where the space of earth raised, or 'struck upwards' by the shock, exceeded the length of the Alps and the Pyrenees.

Hooke's diluvial theory.—As Hooke declared the favourite hypothesis of the day ('that marine fossil bodies were to be referred to Noah's flood') to be wholly untenable, he appears to have felt himself called upon to substitute a diluvial theory of his own, and thus he became involved in countless difficulties and contradictions. 'During the great catastrophe,' he

* Posth. Works, p. 312.

said, 'there might have been a changing of that part which was before dry land into sea by sinking, and of that which was sea into dry land by raising, and marine bodies might have been buried in sediment beneath the ocean, in the interval between the creation and the deluge *.' Then followed a disquisition on the separation of the land from the waters, mentioned in Genesis: during which operation some places of the shell of the earth were forced outwards, and others pressed downwards or inwards, &c. His diluvial hypothesis very much resembled that of Steno, and was entirely opposed to the fundamental principles professed by him, that he would explain the former changes of the earth *in a more natural manner* than others had done. When, in despite of this declaration, he required a former 'crisis of nature,' and taught that earthquakes had become debilitated, and that the Alps, Andes, and other chains, had been lifted up in a few months, his machinery was as extravagant and visionary as that of his most fanciful predecessors; and for this reason, perhaps, his whole theory of earthquakes met with undeserved neglect.

Ray, 1692.—One of his contemporaries, the celebrated naturalist, Ray, participated in the same desire to explain geological phenomena, by reference to causes less hypothetical than those usually resorted to †. In his Essay on 'Chaos and Creation,' he proposed a system, agreeing in its outline, and in many of its details, with that of Hooke; but his knowledge of natural history enabled him to elucidate the subject with various original observations. Earthquakes, he suggested, might have been the second causes employed at the creation, in separating the land from the waters, and in gathering the waters together into one place. He mentions, like Hooke, the earthquake of 1646, which had violently shaken the Andes for

* Posth. Works, p. 410.

† Ray's Physico-theological Discourses were of somewhat later date than Hooke's great work on earthquakes. He speaks of Hooke as one 'whom for his learning and deep insight into the mysteries of nature he deservedly honoured.' —*On the Deluge*, chap. iv.

some hundreds of leagues, and made many alterations therein. In assigning a cause for the general deluge, he preferred a change in the earth's centre of gravity to the introduction of earthquakes. Some unknown cause, he said, might have forced the subterranean waters outwards, as was, perhaps, indicated by 'the breaking up of the fountains of the great deep.'

Ray was one of the first of our writers who enlarged upon the effects of running water upon the land, and of the encroachment of the sea upon the shores. So important did he consider the agency of these causes, that he saw in them an indication of the tendency of our system to its final dissolution; and he wondered why the earth did not proceed more rapidly towards a general submersion beneath the sea, when so much matter was carried down by rivers, or undermined in the sea-cliffs. We perceive clearly from his writings, that the gradual decline of our system, and its future consummation by fire, was held to be as necessary an article of faith by the orthodox, as was the recent origin of our planet. His Discourses, like those of Hooke, are highly interesting, as attesting the familiar association in the minds of philosophers, in the age of Newton, of questions in physics and divinity. Ray gave an unequivocal proof of the sincerity of his mind, by sacrificing his preferment in the church, rather than take an oath against the Covenanters, which he could not reconcile with his conscience. His reputation, moreover, in the scientific world placed him high above the temptation of courting popularity, by pandering to the physico-theological taste of his age. It is, therefore, curious to meet with so many citations from the Christian fathers and prophets in his essays on physical science—to find him in one page proceeding, by the strict rules of induction, to explain the former changes of the globe, and in the next gravely entertaining the question, whether the sun and stars, and the whole heavens shall be annihilated, together with the earth, at the era of the grand conflagration.

Woodward, 1695.—Among the contemporaries of Hooke

and Ray, Woodward, a professor of medicine, had acquired the most extensive information respecting the geological structure of the crust of the earth. He had examined many parts of the British strata with minute attention; and his systematic collection of specimens, bequeathed to the University of Cambridge, and still preserved there as arranged by him, shows how far he had advanced in ascertaining the order of superposition. From the great number of facts collected by him, we might have expected his theoretical views to be more sound and enlarged than those of his contemporaries; but in his anxiety to accommodate all observed phenomena to the scriptural account of the Creation and Deluge, he arrived at most erroneous results. He conceived 'the whole terrestrial globe to have been taken to pieces and dissolved at the flood, and the strata to have settled down from this promiscuous mass as any earthy sediment from a fluid *.' In corroboration of these views, he insisted upon the fact, that 'marine bodies are lodged in the strata according to the order of their gravity, the heavier shells in stone, the lighter in chalk, and so of the rest †.' Ray immediately exposed the unfounded nature of this assertion, remarking truly, that fossil bodies 'are often mingled, heavy with light, in the same stratum;' and he even went so far as to say, that Woodward 'must have invented the phenomena for the sake of confirming his bold and strange hypothesis ‡'—a strong expression from the pen of a contemporary.

Burnet, 1690.—At the same time Burnet published his 'Theory of the Earth §.' The title is most characteristic of the age,—'The Sacred Theory of the Earth, containing an Account of the Original of the Earth, and of all the general Changes which it hath already undergone, or is to undergo, till the Consummation of all Things.' Even Milton had scarcely ventured in his poem to indulge his imagination so

* Essay towards a Natural History of the Earth, 1695. Preface.

† Ibid. Preface.

‡ Consequences of the Deluge, p. 165.

§ First published in Latin between the years 1680 and 1690.

freely in painting scenes of the Creation and Deluge, Paradise and Chaos, as this writer, who set forth pretensions to profound philosophy. He explained why the primeval earth enjoyed a perpetual spring before the flood! showed how the crust of the globe was fissured by 'the sun's rays,' so that it burst, and thus the diluvial waters were let loose from a supposed central abyss. Not satisfied with these themes, he derived from the books of the inspired writers, and even from heathen authorities, prophetic views of the future revolutions of the globe, gave a most terrific description of the general conflagration, and proved that a new heaven and a new earth will rise out of a *second chaos*—after which will follow the blessed millennium.

The reader should be informed, that, according to the opinion of many respectable writers of that age, there was good scriptural ground for presuming that the garden bestowed upon our first parents was not on the earth itself, but above the clouds, in the middle region between our planet and the moon. Burnet approaches with becoming gravity the discussion of so important a topic. He was willing to concede that the geographical position of Paradise was not in Mesopotamia, yet he maintained that it was upon the earth, and in the southern hemisphere, near the equinoctial line. Butler selected this conceit as a fair mark for his satire, when, amongst the numerous accomplishments of Hudibras, he says—

> He knew the seat of Paradise,
> Could tell in what degree it lies;
> And, as he was disposed, could prove it
> Below the moon, or else above it.

Yet the same monarch, who is said never to have slept without Butler's poem under his pillow, was so great an admirer and patron of Burnet's book, that he ordered it to be translated from the Latin into English. The style of the 'Sacred Theory' was eloquent, and displayed powers of invention of no ordinary stamp. It was, in fact, a fine historical romance, as Buffon afterwards declared; but it was treated as a work of profound science in the time of its author, and was panegy-

rized by Addison in a Latin ode, while Steele praised it in the 'Spectator,' and Warton, in his 'Essay on Pope,' discovered that Burnet united the faculty of *judgment* with powers of imagination.

Whiston, 1696.—Another production of the same school, and equally characteristic of the time, was that of Whiston, entitled, 'A New Theory of the Earth, wherein the Creation of the World in Six Days, the Universal Deluge, and the General Conflagration, as laid down in the Holy Scriptures, are shewn to be perfectly agreeable to Reason and Philosophy.' He was at first a follower of Burnet, but his faith in the infallibility of that writer was shaken by the declared opinion of Newton, that there was every presumption in astronomy against any former change in the inclination of the earth's axis. This was a leading dogma in Burnet's system, though not original, for it was borrowed from an Italian, Alessandro degli Alessandri, who had suggested it in the beginning of the fifteenth century, to account for the former occupation of the present continents by the sea. La Place has since strengthened the arguments of Newton, against the probability of any former revolution of this kind.

The remarkable comet of 1680 was fresh in the memory of every one when Whiston first began his cosmological studies, and the principal novelty of his speculations consisted in attributing the deluge to the near approach to the earth of one of these erratic bodies. Having ascribed an increase of the waters to this source, he adopted Woodward's theory, supposing all stratified deposits to have resulted from the 'chaotic sediment of the flood.' Whiston was one of the first who ventured to propose that the text of Genesis should be interpreted differently from its ordinary acceptation, so that the doctrine of the earth having existed long previous to the creation of man might no longer be regarded as unorthodox. He had the art to throw an air of plausibility over the most improbable parts of his theory, and seemed to be proceeding in the most sober manner, and by the aid of mathematical demonstration, to the

establishment of his various propositions. Locke pronounced a panegyric on his theory, commending him for having explained so many wonderful and before inexplicable things. His book, as well as Burnet's, was attacked and refuted by Keill *. Like all who introduced purely hypothetical causes to account for natural phenomena, Whiston retarded the progress of truth, diverting men from the investigation of the laws of sublunary nature, and inducing them to waste time in speculations on the power of comets to drag the waters of the ocean over the land—on the condensation of the vapours of their tails into water, and other matters equally edifying.

Hutchinson, 1724.—John Hutchinson, who had been employed by Woodward in making his collection of fossils, published afterwards, in 1724, the first part of his 'Moses's Principia,' wherein he ridiculed Woodward's hypothesis. He and his numerous followers were accustomed to declaim loudly against human learning, and they maintained that the Hebrew scriptures, when rightly translated, comprised a perfect system of natural philosophy, for which reason they objected to the Newtonian theory of gravitation.

Leibnitz, 1680.—Leibnitz, the great mathematician, published his 'Protogæa' in 1680. He imagined this planet to have been originally a burning luminous mass, and that ever since its creation it has been undergoing gradual refrigeration. Nearly all the matter of the earth was at first encompassed by fire. When the outer crust had at length cooled down sufficiently to allow the vapours to be condensed, they fell and formed a universal ocean, investing the globe, and covering the loftiest mountains. Further consolidation produced rents, vacuities, and subterranean caverns, and the ocean, rushing in to fill them, was gradually lowered. The principal feature of this theory, the gradual diminution of the original heat, and of an ancient universal ocean, were adopted by Buffon and De Luc, and entered, under different modifications, into a great number of succeeding systems.

* An Examination of Dr. Burnet's Theory, &c. 2d edition, 1734.

Celsius.—Andrea Celsius, the Swedish astronomer, published about this time his remarks on the gradual diminution of the waters in the Baltic, which sea, he imagined, had been sinking from time immemorial at the rate of forty-five inches in a century. His opinions gave rise to a controversy which has lasted even to our own days, and to which we are indebted for correct observations of a variety of facts concerning the gradual filling up of the Baltic by fluviatile and marine sediment. Linnæus* favoured the views of Celsius, because they fell in with his own notions concerning a Paradise, where all the animals were created, and from whence they passed into all other parts of the earth, as these became dry in succession.

Scheuchzer, 1708.—In Germany, in the mean time, Scheuchzer laboured to prove, in a work entitled the 'Complaint of the Fishes' (1708), that the earth had been remodelled at the deluge. Pluche also, in 1732, wrote to the same effect, while Holbach, in 1753, after considering the various attempts to refer all the ancient formations to the Noachian flood, exposed the insufficiency of the cause.

Italian Geologists—Vallisneri.—We return with pleasure to the geologists of Italy, who preceded, as we before saw, the naturalists of other countries in their investigations into the ancient history of the earth, and who still maintained a decided pre-eminence. They refuted and ridiculed the physico-theological systems of Burnet, Whiston, and Woodward †, while Vallisneri ‡, in his comments on the Woodwardian theory, remarked how much the interests of religion, as well as those of sound philosophy, had suffered by perpetually mixing up the sacred writings with questions in physical science. The works of this author were rich in original observations. He attempted the first general sketch of the marine deposits of

* De Telluris habitabilis Incremento, 1743.

† Ramazzini even asserted, that the ideas of Burnet were mainly borrowed from a dialogue of one Patrizio; but Brocchi, after reading that dialogue, assures us, that there was scarcely any other correspondence between these systems, except that both were equally whimsical.

‡ Dei Corpi Marini, Lettere critiche, &c. 1721.

Italy, their geographical extent, and most characteristic organic remains. In his treatise 'On the Origin of Springs,' he explained their dependence on the order, and often on the dislocations of the strata, and reasoned philosophically against the opinions of those who regarded the disordered state of the earth's crust as exhibiting signs of the wrath of God for the sins of man. He found himself under the necessity of contending in his preliminary chapter against St. Jerome, and four other principal interpreters of scripture, besides several professors of divinity, 'that springs did not flow by subterranean syphons and cavities from the sea upwards, losing their saltness in the passage,' for this theory had been made to rest on the infallible testimony of Holy Writ.

Although reluctant to generalize on the rich materials accumulated in his travels, Vallisneri had been so much struck with the remarkable continuity of the more recent marine strata, from one end of Italy to the other, that he came to the conclusion that the ocean formerly extended over the whole earth, and abode there for a long time. This opinion, however untenable, was a great step beyond Woodward's diluvian hypothesis, against which Vallisneri, and after him all the Tuscan geologists, uniformly contended, while it was warmly supported by the members of the Institute of Bologna*.

Among others of that day, Spada, a priest of Grezzana, in 1737, wrote to prove that the petrified marine bodies near Verona were not diluvian†. Mattani drew a similar inference from the shells of Volterra and other places; while Costantini, on the other hand, whose observations on the valley of the Brenta and other districts were not without value, undertook to vindicate the truth of the deluge, as also to prove that Italy had been peopled by the descendants of Japhet‡.

Moro, 1740.—Lazzaro Moro, in his work (published in 1740) 'On the Marine Bodies which are found in the Mountains§,' attempted to apply the theory of earthquakes, as ex-

* Brocchi, p. 28. † Ibid., p. 33. ‡ Ibid., p. 37.

§ Sui Crostacei ed altri Corpi Marini che si trovano sui Monti.

pounded by Strabo, Pliny, and other ancient authors, with whom he was familiar, to the geological phenomena described by Vallisneri*. His attention was awakened to the elevating power of subterranean forces by a remarkable phenomenon which happened in his own time, and which had also been noticed by Vallisneri in his letters. A new island rose in 1707 from a deep part of the sea near Santorino in the Mediterranean, during continued shocks of an earthquake, and increasing rapidly in size, grew in less than a month to be half a mile in circumference, and about twenty-five feet above high-water mark. It was soon afterwards covered by volcanic ejections, but, when first examined, it was found to be a white rock, bearing on its surface living oysters and crustacea. In order to ridicule the various theories then in vogue, Moro ingeniously supposes the arrival on this new isle of a party of naturalists ignorant of its recent origin. One immediately points to the marine shells, as proofs of the universal deluge; another argues that they demonstrate the former residence of the sea upon the mountains; a third dismisses them as mere *sports of nature;* while a fourth affirms, that they were born and nourished within the rock in ancient caverns, into which salt water had been raised in the shape of vapour by the action of subterranean heat.

Moro pointed with great judgment to the *faults* and dislocations of the strata described by Vallisneri, in the Alps and other chains, in confirmation of his doctrine, that the continents had been heaved up by subterranean movements. He objected, on solid grounds, to the hypotheses of Burnet and of Woodward; yet he ventured so far to disregard the protest of Vallisneri, as to undertake the adaptation of every part of his own system to the Mosaic account of the creation. On the third

* Moro does not cite the works of Hooke and Ray, and although so many of his views were in accordance with theirs, he was probably ignorant of their writings, for they had not been translated. As he always refers to the Latin edition of Burnet, and a French translation of Woodward, we may presume that he did not read English.

day, he said, the globe was every where covered to the same depth by fresh water, and when it pleased the Supreme Being that the dry land should appear, volcanic explosions broke up the smooth and regular surface of the earth composed of primary rocks. These rose in mountain masses above the waves, and allowed melted metals and salts to ascend through fissures. *The sea gradually acquired its saltness from volcanic exhalations*, and, while it became more circumscribed in area, increased in depth. Sand and ashes ejected by volcanos were regularly disposed along the bottom of the ocean and formed the secondary strata, which in their turn were lifted up by earthquakes. We shall not attempt to follow him in tracing the progress of the creation of vegetables and animals, on the other days of creation; but, upon the whole, we may remark that few of the old cosmological theories had been conceived with so little violation of known analogies.

Generelli's illustrations of Moro, 1749.—The style of Moro was extremely prolix, and, like Hutton, who, at a later period, advanced many of the same views, he stood in need of an illustrator. The Scotch geologist was not more fortunate in the advocacy of Playfair, than was Moro in numbering amongst his admirers Cirillo Generelli, who, nine years afterwards, delivered at a sitting of Academicians at Cremona a spirited exposition of his theory. This learned Carmelitan friar does not pretend to have been an original observer, but he had studied sufficiently to be enabled to confirm the opinions of Moro by arguments from other writers; and his selection of the doctrines then best established is so judicious, that we shall present a brief abstract of them to our readers, as illustrating the state of geology in Europe, and in Italy in particular, before the middle of the last century.

The bowels of the earth, says he, have carefully preserved the memorials of past events, and this truth the marine productions so frequent in the hills attest. From the reflections of Lazzaro Moro, we may assure ourselves that these are the effects of earthquakes in past times, which have changed vast

spaces of sea into terra firma, and inhabited lands into seas. In this, more than in any other department of physics, are observations and experiments indispensable, and we must diligently consider facts. The land is known, wherever we make excavations, to be composed of different strata or soils placed one above the other, some of sand, some of rock, some of chalk, others of marl, coal, pumice, gypsum, lime, and the rest. These ingredients are sometimes pure, and sometimes confusedly intermixed. Within are often imprisoned different marine fishes, like dried mummies, and more frequently shells, crustacea, corals, plants, &c., not only in Italy, but in France, Germany, England, Africa, Asia, and America. Sometimes in the lowest, sometimes in the loftiest beds of the earth, some upon the mountains, some in deep mines, others near the sea, and others hundreds of miles distant from it. But there are, in some districts, rocks wherein no marine bodies are found. The remains of animals consist chiefly of their more solid parts, and the most rocky strata must have been soft when such exuviæ were inclosed in them. Vegetable productions are found in different states of maturity, indicating that they were imbedded in different seasons. Elephants, elks, and other terrestrial quadrupeds, have been found in England and elsewhere, in superficial strata, never covered by the sea. Alternations are rare, yet not without example, of marine strata, and those which contain marshy and terrestrial productions. Marine animals are arranged in the subterraneous beds with admirable order, in distinct groups, oysters here, dentalia, or corals there, &c., as now, according to Marsilli *, on the shores of the Adriatic. We must abandon the doctrine once so popular, that organized fossils have not been derived from living beings, and we cannot account for their present position by the ancient theory of Strato, nor by that of Leibnitz, nor by the universal deluge, as explained by Woodward and others, ' nor is it reasonable to call the Deity capriciously upon the stage, and to make him work miracles for the sake of confirming our preconceived

* Saggio fisico intorno alla Storia del Mare, part i. p. 24.

hypotheses.'—'I hold in utter abomination, most learned Academicians! those systems which are built with their foundations in the air, and cannot be propped up without a miracle; and I undertake, with the assistance of Moro, to explain to you, how these marine animals were transported into the mountains by natural causes *.'

A brief abstract then follows of Moro's theory, by which, says Generelli, we may explain all the phenomena, as Vallisneri so ardently desired, '*without violence, without fictions, without hypotheses, without miracles* †.' The Carmelitan then proceeds to struggle against an obvious objection to Moro's system, considered as a method of explaining the revolutions of the earth, *naturally*. If earthquakes have been the agents of such mighty changes, how does it happen that their effects since the times of history have been so inconsiderable? This same difficulty had, as we have seen, presented itself to Hooke, half a century before, and forced him to resort to a former 'crisis of nature;' but Generelli defended his position by shewing how numerous were the accounts of eruptions and earthquakes, of new islands, and of elevations and subsidences of land, and yet how much greater a number of like events must have been unattested and unrecorded during the last six thousand years. He also appealed to Vallisneri as an authority to prove that the mineral masses containing shells bore, upon the whole, but a small proportion to those rocks which were destitute of organic remains; and the latter, says the learned monk, might have been created as they now exist, *in the beginning*.

Generelli then describes the continual waste of mountains and continents, by the action of rivers and torrents, and concludes with these eloquent and original observations: 'Is it possible that this waste should have continued for six thou-

* Abbomino al sommo qualsivoglia sistema, che sia di pianta fabbricato in aria; massime quando è tale, che non possa sostenersi senza un miracolo, &c. De' Crostacei e di altre produz. del Mare, &c. 1749.

† Senza violenze, senza finzioni, senza supposti, senza miracoli.—*Ib.*

sand, and *perhaps* a greater number of years, and that the mountains should remain so great, unless their ruins have been repaired? Is it credible that the Author of nature should have founded the world upon such laws, as that the dry land should for ever be growing smaller, and at last become wholly submerged beneath the waters? Is it credible that, amid so many created things, the mountains alone should daily diminish in number and bulk, without there being any repair of their losses? This would be contrary to that order of Providence which is seen to reign in all other things in the universe. Wherefore I deem it just to conclude, that the same cause which, in the beginning of time, raised mountains from the abyss, has, down to the present day, continued to produce others, in order to restore from time to time the losses of all such as sink down in different places, or are rent asunder, or in other ways suffer disintegration. If this be admitted, we can easily understand why there should now be found upon many mountains so great a number of crustacea and other marine animals.'

The reader will remark, that although this admirable essay embraces so large a portion of the principal objects of geological research, it makes no allusion to the extinction of certain classes of animals; and it is evident that no opinions on this head had, at that time, gained a firm footing in Italy. That Lister and other English naturalists should long before have declared in favour of the loss of species, while Scilla and most of his countrymen hesitated, was natural, since the Italian museums were filled with fossil shells, belonging to species of which a great portion did actually exist in the Mediterranean, whereas the English collectors could obtain no recent species from such of their own strata as were then explored.

The weakest point in Moro's system consisted in deriving *all* the stratified rocks from volcanic ejections, an absurdity which his opponents took care to expose, especially Vito Amici*. Moro seems to have been misled by his anxious

* Sui Testacei della Sicilia.

desire to represent the formation of secondary rocks as having occupied an extremely short period, while at the same time he wished to employ known agents in nature. To imagine torrents, rivers, currents, partial floods, and all the operations of moving water, to have gone on exerting an energy many thousand times greater than at present, would have appeared preposterous and incredible, and would have required a hundred violent hypotheses; but we are so unacquainted with the true sources of subterranean disturbances, that their former violence may in theory be multiplied indefinitely, without its being possible to prove the same manifest contradiction or absurdity in the conjecture. For this reason, perhaps, Moro preferred to derive the materials of the strata from volcanic ejections, rather than from transportation by running water.

Marsilli.—Marsilli, in the work above alluded to by Generelli, had been prompted to institute inquiries into the bed of the Adriatic, by discovering in the territory of Parma, (what Spada had observed near Verona, and Schiavo in Sicily,) that fossil shells were not scattered through the rocks at random, but disposed in regular order, according to certain genera and species.

Vitaliano Donati, 1750.—But with a view of throwing further light upon these questions, Donati, in 1750, undertook a more extensive investigation of the Adriatic, and discovered, by numerous soundings, that deposits of sand, marl, and tufaceous incrustations, most strictly analogous to those of the Subapennine hills, were in the act of accumulating there. He ascertained that there were no shells in some of the submarine tracts, while in other places they lived together in families, particularly the genera Arca, Pecten, Venus, Murex, and some others. He also states that in divers localities he found a mass composed of corals, shells and crustaceous bodies of different species confusedly blended with earth, sand and gravel. At the depth of a foot or more the organic substances were entirely petrified and reduced to marble; at less than a foot from the surface they approached nearer to their natural

state, while at the surface they were alive or dead, but in a good state of preservation.

Baldassari.—A contemporary naturalist, Baldassari, had shown that the organic remains in the tertiary marls of the Siennese territory were grouped in families, in a manner precisely similar to that above alluded to by Donati.

Buffon, 1749.—Buffon first made known his theoretical views concerning the former changes of the earth in his Natural History, published in 1749. His opinions were directly opposed to the systems of Hooke, Ray and Moro, for he attributed no influence whatever to subterranean movements and volcanos, but returned to the universal ocean of Leibnitz. By this aqueous envelope the highest mountains were once covered. Marine currents then acted violently, and formed horizontal strata, by washing away land in some parts, and depositing it in others; they also excavated deep submarine valleys. He was greatly at a loss for some machinery to depress the level of the ocean, and cause the land to be left dry. He therefore speculated on the possibility of subterranean caverns having opened, into which the water entered, so that he involuntarily approximated to Hooke's theory of subsidences by earthquakes. Buffon had never profited, like Moro, by the observations of Vallisneri, or he never could have imagined that the strata were generally horizontal, and that those which contain organic remains had never been disturbed since the era of their formation. He was conscious of the great power annually exerted by rivers and marine currents in transporting earthy materials to lower levels, and he even contemplated the period when they would destroy all the present continents. Although in geology he was not an original observer, his genius enabled him to render his hypothesis attractive; and by the eloquence of his style, and the boldness of his speculations, he awakened curiosity and provoked a spirit of inquiry amongst his countrymen.

Soon after the publication of his 'Natural History,' in which was included his 'Theory of the Earth,' he received an official letter (dated January, 1751), from the Sorbonne or

Faculty of Theology in Paris, informing him that fourteen propositions in his works 'were reprehensible and contrary to the creed of the church.' The first of these obnoxious passages, and the only one relating to geology, was as follows. 'The waters of the sea have produced the mountains and valleys of the land—the waters of the heavens, reducing all to a level, will at last deliver the whole land over to the sea, and the sea, successively prevailing over the land, will leave dry new continents like those which we inhabit.' Buffon was invited by the College, in very courteous terms, to send in an explanation, or rather a recantation, of his unorthodox opinions. To this he submitted, and a general assembly of the Faculty having approved of his 'Declaration,' he was required to publish it in his next work. The document begins with these words—'I declare that I had no intention to contradict the text of Scripture; that I believe most firmly all therein related about the creation, both as to order of time and matter of fact; and *I abandon every thing in my book respecting the formation of the earth,* and generally all which may be contrary to the narration of Moses *.'

The grand principle which Buffon was called upon to renounce was simply this,—'that the present mountains and valleys of the earth are due to secondary causes, and that the same causes will in time destroy all the continents, hills and valleys, and reproduce others like them.' Now, whatever may be the defects of many of his views, it is no longer controverted, that the present continents are of secondary origin. The doctrine is as firmly established as the earth's rotation on its axis; and that the land now elevated above the level of the sea will not endure for ever, is an opinion which gains ground daily, in proportion as we enlarge our experience of the changes now in progress.

Hollman, 1753.—Hollman was the author of a Memoir in the Transactions of the Royal Society of Gottingen in 1753, wherein he proposed an hypothesis closely corresponding to the

* Hist. Nat. tom. v. Ed. de l'Imp. Royale, Paris, 1769.

opinions of Buffon; and devoted the rest of his work to refuting certain diluvial theories of his day.

Targioni, 1751.—Targioni, in his voluminous 'Travels in Tuscany, 1751 and 1754,' laboured to fill up the sketch of the geology of that region, left by Steno sixty years before. Notwithstanding a want of arrangement and condensation in his memoirs, they contained a rich store of faithful observations. He has not indulged in many general views, but in regard to the origin of valleys he was opposed to the theory of Buffon, who attributed them principally to submarine currents. The Tuscan naturalist laboured to shew that both the larger and smaller valleys of the Apennines were excavated by rivers, and floods, caused by the bursting of the barriers of lakes, after the retreat of the ocean. He also maintained that the elephants, and other quadrupeds so frequent in the lacustrine and alluvial deposits of Italy, had inhabited that peninsula; and had not been transported thither, as some had conceived, by Hannibal, or the Romans, nor by what they were pleased to term 'a catastrophe of nature.'

Lehman, 1756.—In the year 1756 the treatise of Lehman*, a German mineralogist, and director of the Prussian mines, appeared, who also divided mountains into three classes: the first, which were formed with the world and prior to the creation of animals, and which contained no fragments of other rocks; the second class, of mountains which resulted from the partial destruction of the primary rocks by a general revolution; and the third class, which resulted from local revolutions, and in part from the Noachian deluge.

A French translation of this work appeared in 1759, in the preface of which the translator displays very enlightened views respecting the operations of earthquakes, as well as of the aqueous causes.

Arduino, 1759.—In the same year (1759) Arduino†, in his memoirs on the mountains of Padua, Vicenza, and Verona,

* Essai d'une Hist. Nat. de Couches de la Terre, 1759.

† Giornale del Griselini, 1759.

deduced, from original observations, the distinction of rocks into primary, secondary, and tertiary, and shewed that in those districts there had been a succession of submarine volcanic eruptions.

Michell, 1760.—In the following year (1760) the Rev. John Michell, Woodwardian Professor of Mineralogy at Cambridge, published, in the Philosophical Transactions, an Essay on the Cause and Phenomena of Earthquakes. His attention had been drawn to this subject by the great earthquake of Lisbon in 1755. He advanced many original and philosophical views respecting the propagation of subterranean movements, and the caverns and fissures wherein steam might be generated. In order to point out the application of his theory to the structure of the globe, he was led to describe the arrangement and disturbance of the strata, their usual horizontality in low countries, and their contortions and fractured state in the neighbourhood of mountain chains. He also explained, with surprising accuracy, the relations of the central ridges of older rocks to the 'long narrow slips of similar earths, stones, and minerals,' which are parallel to these ridges. In his generalizations, derived in great part from his own observations on the geological structure of Yorkshire, he anticipated many of the views more fully developed by later naturalists *.

Catcott, 1761.—Michell's papers were entirely free from all physico-theological disquisitions, but some of his contemporaries were still earnestly engaged in defending or impugning the Woodwardian hypothesis. We find many of these writings referred to by Catcott, an Hutchinsonian, who published a 'Treatise on the Deluge' in 1761. He laboured particularly to refute an explanation offered by his contemporary, Bishop Clayton, of the Mosaic writings. That prelate had declared that the Deluge 'could not be literally true, save in respect to that part where

* Some of Michell's observations anticipate in so remarkable a manner the theories established forty years afterwards, that his writings would probably have formed an era in the science, if his researches had been uninterrupted. He held, however, his professorship only eight years, when he succeeded to a benefice, and from that time he appears to have entirely discontinued his scientific pursuits.

Noah lived before the flood.' Catcott insisted on the universality of the deluge, and referred to traditions of inundations mentioned by ancient writers, or by travellers in the East-Indies, China, South America, and other countries. This part of his book is valuable, although it is not easy to see what bearing the traditions have, if admitted to be authentic, on the Bishop's argument, since no evidence is adduced to prove that the catastrophes were contemporaneous events, while some of them are expressly represented by ancient authors to have occurred in succession.

Fortis—Odoardi, 1761.—The doctrines of Arduino, above adverted to, were afterwards confirmed by Fortis and Desmarest, in their travels in the same country; and they, as well as Baldassari, laboured to complete the history of the Subapennine strata. In the work of Odoardi*, there was also a clear argument in favour of the distinct ages of the older Apennine strata, and the Subapennine formations of more recent origin. He pointed out that the strata of these two groups were *unconformable*, and must have been the deposits of different seas at distant periods of time.

Raspe, 1763.—A history of the new islands by Raspe, an Hanoverian, appeared in 1763, in Latin†. In this work, all the authentic accounts of earthquakes which had produced permanent changes on the solid parts of the earth were collected together and examined with judicious criticism. The best systems which had been proposed concerning the ancient history of the globe, both by ancient and modern writers, are reviewed. The merits and defects of the systems of Hooke, Ray, Moro, Buffon, and others, are fairly estimated. Great admiration is expressed for the hypothesis of Hooke, and his explanation of the origin of the strata is shown to have been more correct than Moro's, while their theory of the effects of earthquakes was the same. Raspe had not seen Michell's

* Sui Corpi Marini del Feltrino, 1761.

† De Novis e Mari Natis Insulis. Raspe was also the editor of the 'Philosophical Works of Leibnitz. Amst. et Leipzig, 1765;' also author of 'Tassie's Gems,' and 'Baron Munchausen's Travels.'

memoir, and his views concerning the geological structure of the earth were perhaps less enlarged; yet he was able to add many additional arguments in favour of Hooke's theory, and to render it, as he said, a nearer approach to what Hooke would have written had he lived in later times. As to the periods wherein all the earthquakes happened, to which we owe the elevation of various parts of our continents and islands, Raspe says he pretends not to assign their duration, still less to defend Hooke's suggestion, that the convulsions almost all took place during the Noachian deluge. He adverts to the apparent indications of the former tropical heat of the climate of Europe, and the changes in the species of animals and plants, as among the most obscure and difficult problems in geology. In regard to the islands raised from the sea, within the times of history or tradition, he declares that some of them were composed of strata containing organic remains, and that they were not, as Buffon had asserted, made of mere volcanic matter. His work concludes with an eloquent exhortation to naturalists, to examine the isles which rose in 1707, in the Grecian Archipelago, and in 1720 in the Azores, and not to neglect such splendid opportunities of studying nature 'in the act of parturition.' That Hooke's writings should have been neglected for more than half a century, was matter of astonishment to Raspe; but it is still more wonderful that his own luminous exposition of that theory should, for more than another half century, have excited so little interest.

Brander, 1766.—Gustavus Brander published, in 1766, his 'Fossilia Hantoniensia,' containing excellent figures of fossil shells from the more modern marine strata of our island. 'Various opinions,' he says in the preface, 'had been entertained concerning the time when and how these bodies became deposited. Some there are who conceive that it might have been effected in a wonderful length of time by a gradual changing and shifting of the sea,' &c. But the most common cause assigned is that of 'the deluge.' This conjecture, he says, even if the universality of the flood be not called in question, is purely

hypothetical. In his opinion fossil animals and testacea were, for the most part, of unknown species, and of such as were known, the living analogues now belonged to southern latitudes.

Soldani, 1780.—Soldani * applied successfully his knowledge of zoology to illustrate the history of stratified masses. He explained that microscopic testacea and zoophytes inhabited the depths of the Mediterranean, and that the fossil species were, in like manner, found in those deposits wherein the fineness of their particles, and the absence of pebbles, implied that they were accumulated in a deep sea far from any shore. This author first remarked the alternation of marine and fresh-water strata in the Paris basin.

Fortis—Testa, 1793.—A lively controversy arose between Fortis and another Italian naturalist, Testa, concerning the fish of Monte Bolca, in 1793. Their letters †, written with great spirit and elegance, show that they were aware that a large proportion of the Subapennine shells were identical with living species, and some of them with species now living in the torrid zone. Fortis conjectured that when the volcanos of the Vicentin were burning, the waters of the Adriatic had a higher temperature; and in this manner, he said, that the shells of warmer regions may once have peopled their own seas. But Testa was disposed to think, that these species of testacea were still common to their own and to equinoctial seas; for many, he said, once supposed to be confined to hotter regions, had been afterwards discovered in the Mediterranean ‡.

* Saggio orittografico, &c., 1780, and other Works.

† Lett. sui Pesci Fossili di Bolca. Milan, 1793.

‡ This argument of Testa has been strengthened of late years by the discovery, that dealers in shells had long been in the habit of selling Mediterranean species as shells of more southern and distant latitudes, for the sake of enhancing their price. It appears, moreover, from several hundred experiments made by that distinguished hydrographer Captain Smyth, on the water within eight fathoms of the surface, that the temperature of the Mediterranean is on an average 3½° of Fahrenheit higher than the western part of the Atlantic ocean; an important fact, which in some degree may help to explain why many species are common to tropical latitudes and to the Mediterranean.

Cortesi—Spallanzani—Wallerius—Whitehurst. — While these Italian naturalists, together with Cortesi and Spallanzani, were busily engaged in pointing out the analogy between the deposits of modern and ancient seas, and the habits and arrangement of their organic inhabitants, and while some progress was making, in the same country, in investigating the ancient and modern volcanic rocks, the most original observers among the English and German writers, Wallerius and Whitehurst *, were wasting their strength in contending, according to the old Woodwardian hypothesis, that all the strata were formed by the Noachian deluge. But Whitehurst's description of the rocks of Derbyshire was most faithful, and he atoned for false theoretical views, by providing data for their refutation.

Boscovich, 1772.—The mathematician, Boscovich, of Ragusa in Dalmatia, in his letters, published at Venice in 1772, declared his persuasion, that the effects of earthquakes, although insensible in the course of a few years, do nevertheless raise, from time to time, and let down different parts of the crust of our globe, and sometimes fold and twist them. Like Hooke, Ray, and Moro, he conceived the subterranean movements to have acted with greater energy at former epochs.

Pallas—Saussure.—Towards the close of the eighteenth century, the idea of distinguishing the mineral masses on our globe into separate groups, and studying their relations, began to be generally diffused. Pallas and Saussure were among the most celebrated whose labours contributed to this end. After an attentive examination of the two great mountain chains of Siberia, Pallas announced the result, that the granitic rocks were in the middle, the schistose at their sides, and the limestones again on the outside of these; and this he conceived would prove a general law in the formation of all chains composed chiefly of primary rocks †.

In his 'Travels in Russia,' in 1793 and 1794, he made many geological observations on the recent strata near the

* Inquiry into the Original State and Formation of the Earth. 1778.

† Observ. on the Formation of Mountains, Act. Petrop. ann. 1778, part i.

Wolga and the Caspian, and adduced proofs of the greater extent of the latter sea at no distant era in the earth's history. His memoir on the fossil bones of Siberia attracted attention to some of the most remarkable phenomena in geology. He stated that he had found a rhinoceros entire in the frozen soil, with its skin and flesh: an elephant, found afterwards in a mass of ice on the shore of the North sea, removed all doubt as to the accuracy of so wonderful a discovery *.

The subjects relating to natural history which engaged the attention of Pallas were too multifarious to admit of his devoting a large share of his labours exclusively to geology. Saussure, on the other hand, employed the chief portion of his time in studying the structure of the Alps and Jura, and he provided valuable data for those who followed him. We cannot enter into the details of these observations, and he did not pretend to have arrived at any general system. The few theoretical observations which escaped from him are, like those of Pallas, mere modifications of the old cosmological doctrines.

* Nov. comm. Petr. XVII. Cuvier, Éloge de Pallas.

CHAPTER IV.

Werner's application of Geology to the art of Mining—Excursive character of his Lectures—Enthusiasm of his pupils—His authority—His theoretical errors—Desmarest's Map and Description of Auvergne—Controversy between the Vulcanists and Neptunists—Intemperance of the rival Sects—Hutton's Theory of the Earth—His discovery of Granite Veins—Originality of his Views—Why opposed—Playfair's Illustrations—Influence of Voltaire's Writings on Geology—Imputations cast on the Huttonians by Williams, Kirwan, and De Luc—Smith's Map of England—Geological Society of London—Progress of the Science in France—Growing Importance of the Study of Organic Remains.

Werner.—The art of mining has long been taught in France, Germany, and Hungary, in scientific institutions established for that purpose, where mineralogy has always been a principal branch of instruction *.

Werner was named, in 1775, professor of that science in the 'School of Mines' at Freyberg in Saxony. He directed his attention not merely to the composition and external characters of minerals, but also to what he termed 'geognosy,' or the natural position of minerals in particular rocks, together with the grouping of those rocks, their geographical distribution, and various relations. The phenomena observed in the structure of the globe had hitherto served for little else than to furnish interesting topics for philosophical discussion; but when Werner pointed out their application to the practical purposes of mining, they were instantly regarded by a large class of men as an essential part of their professional education, and from that time the science was cultivated in Europe more ardently and systematically. Werner's mind was at once ima-

* Our miners have been left to themselves, almost without the assistance of scientific works in the English language, and without any 'school of mines,' to blunder their own way into a certain degree of practical skill. The inconvenience of this want of system in a country where so much capital is expended, and often wasted, in mining adventures, has been well exposed by an eminent practical miner.—See 'Prospectus of a School of Mines in Cornwall, by J. Taylor, 1825.'

ginative and richly stored with miscellaneous knowledge. He associated everything with his favourite science, and in his excursive lectures he pointed out all the economical uses of minerals, and their application to medicine; the influence of the mineral composition of rocks upon the soil, and of the soil upon the resources, wealth, and civilization of man. The vast sandy plains of Tartary and Africa, he would say, retained their inhabitants in the shape of wandering shepherds; the granitic mountains and the low calcareous and alluvial plains gave rise to different manners, degrees of wealth and intelligence. The history even of languages, and the migrations of tribes had, according to him, been determined by the direction of particular strata. The qualities of certain stones used in building would lead him to descant on the architecture of different ages and nations, and the physical geography of a country frequently invited him to treat of military tactics. The charm of his manners and his eloquence kindled enthusiasm in the minds of all his pupils, many of whom only intended at first to acquire a slight knowledge of mineralogy; but when they had once heard him, they devoted themselves to it as the business of their lives. In a few years a small school of mines, before unheard of in Europe, was raised to the rank of a great university, and men already distinguished in science studied the German language, and came from the most distant countries to hear the great oracle of geology *.

Werner had a great antipathy to the mechanical labour of writing, and he could never be persuaded to pen more than a few brief memoirs, and those containing no development of his general views. Although the natural modesty of his disposition was excessive, approaching even to timidity, he indulged in the most bold and sweeping generalizations, and he inspired all his scholars with a most implicit faith in his doctrines. Their admiration of his genius, and the feelings of gratitude and friendship which they all felt for him, were not undeserved; but the supreme authority usurped by him over the opinions of

* Cuvier, Éloge de Werner.

his contemporaries, was eventually prejudicial to the progress of the science, so much so, as greatly to counterbalance the advantages which it derived from his exertions. If it be true that delivery be the first, second, and third requisite in a popular orator, it is no less certain that to travel is of threefold importance to those who desire to originate just and comprehensive views concerning the structure of our globe, and Werner had never travelled to distant countries. He had merely explored a small portion of Germany, and conceived, and persuaded others to believe, that the whole surface of our planet, and all the mountain chains in the world, were made after the model of his own province. It was a ruling object of ambition in the minds of his pupils to confirm the generalizations of their great master, and to discover in the most distant parts of the globe his 'universal formations,' which he supposed had been each in succession simultaneously precipitated over the whole earth from a common menstruum, or 'chaotic fluid.' Unfortunately, the limited district examined by the Saxon professor was no type of the world, nor even of Europe; and when the ingenuity of his scholars had tortured the phenomena of distant countries into conformity with his theoretical standard, it was discovered that 'the master' had misinterpreted many of the appearances in the immediate neighbourhood of Freyberg.

Thus, for example, within a day's journey of his school, the porphyry, called by him primitive, has been found not only to send forth veins or dikes through strata of the coal formation, but to overlie them in mass. The granite of the Hartz mountains, on the other hand, which he supposed to be the nucleus of the chain, is now well known to traverse and breach the other beds, penetrating even into the plain (as near Goslar); and nearer Freyberg, in the Erzgebirge, the mica slate does not mantle round the granite, as the professor supposed, but abuts abruptly against it. But it is still more remarkable, that in the Hartz mountains all his flötz rocks, which he represented as horizontal, are highly inclined, and often nearly

vertical, as the chalk at Goslar, and the green sand near Blankenberg*.

The principal merit of Werner's system of instruction consisted in steadily directing the attention of his scholars to the constant relations of certain mineral groups, and their regular order of superposition. But he had been anticipated, as we have shewn in the last chapter, in the discovery of this general law, by several geologists in Italy and elsewhere; and his leading divisions of the secondary strata were at the same time made the basis of an arrangement of the British strata by our countryman, William Smith, to whose work we shall return by-and-by.

Controversy between the Vulcanists and Neptunists.—In regard to basalt and other igneous rocks, Werner's theory was original, but it was also extremely erroneous. The basalts of Saxony and Hesse, to which his observations were chiefly confined, consisted of tabular masses capping the hills, and not connected with the levels of existing valleys, like many in Auvergne and the Vivarais. These basalts, and all other rocks of the same family in other countries, were, according to him, chemical precipitates from water. He denied that they were the products of submarine volcanos, and even taught that, in the primeval ages of the world, there were no volcanos. His theory was opposed, in a two-fold sense, to the doctrine of uniformity in the course of nature; for not only did he introduce, without scruple, many imaginary causes supposed to have once effected great revolutions in the earth, and then to have become extinct, but new ones also were feigned to have come into play in modern times; and, above all, that most violent instrument of change, the agency of subterranean fire.

So early as 1768, before Werner had commenced his mineralogical studies, Raspe had truly characterized the basalts of Hesse as of igneous origin. Arduino, as we have already seen,

* I am indebted for this information to Messrs. Sedgwick and Murchison, who have investigated this country.

had pointed out numerous varieties of trap-rock in the Vicentin, as analogous to volcanic products, and as distinctly referrible to ancient submarine eruptions. Desmarest, as we stated, had, in company with Fortis, examined the Vicentin in 1766, and confirmed Arduino's views. In 1772, Banks, Solander, and Troil compared the columnar basalt of Hecla with that of the Hebrides. Collini, in 1774, recognized the true nature of the igneous rocks on the Rhine, between Andernach and Bonn. In 1775, Guettard visited the Vivarais, and established the relation of basaltic currents to lavas. Lastly, in 1779, Faujas published his description of the volcanos of the Vivarias and Velay, and shewed how the streams of basalt had poured out from craters which still remain in a perfect state*.

Desmarest.—When sound opinions had for twenty years prevailed in Europe concerning the true nature of the ancient trap-rocks, Werner by his dictum caused a retrograde movement, and not only overturned the true theory, but substituted for it one of the most unphilosophical ever advanced in any science. The continued ascendency of his dogmas on this subject was the more astonishing, because a variety of new and striking facts were daily accumulated in favour of the correct opinions first established. Desmarest, after a careful examination of Auvergne, pointed out first the most recent volcanos which had their craters still entire, and their streams of lava conforming to the level of the present river-courses. He then shewed that there were others of an intermediate epoch, whose craters were nearly effaced, and whose lavas were less intimately connected with the present valleys; and, lastly, that there were volcanic rocks still more ancient, without any discernible craters or scoriæ, and bearing the closest analogy to rocks in other parts of Europe, the igneous origin of which was denied by the school of Freyberg †.

Desmarest's map of Auvergne was a work of uncommon

* Cuvier, Éloge de Desmarest.

† Journ. de Phys., vol. xiii. p. 115; and Mem. de l'Inst. Sciences, Mathémat. et Phys., vol. vi. p. 219.

merit. He first made a trigonometrical survey of the district, and delineated its physical geography with minute accuracy and admirable graphic power. He contrived, at the same time, to express, without the aid of colours, a vast quantity of geological detail, the different ages, and sometimes even the structure of the volcanic rocks, distinguishing them from the fresh-water and the granitic. They alone who have carefully studied Auvergne, and traced the different lava-streams from their craters to their termination,—the various isolated basaltic cappings,—the relation of some lavas to the present valleys,—the absence of such relations in others,—can appreciate the extraordinary fidelity of this elaborate work. No other district of equal dimensions in Europe exhibits, perhaps, so beautiful and varied a series of phenomena; and, fortunately, Desmarest possessed at once the mathematical knowledge required for the construction of a map, skill in mineralogy, and a power of original generalization.

Dolomieu—Montlosier.—Dolomieu, another of Werner's contemporaries, had found prismatic basalts among the ancient lavas of Etna, and in 1784 had observed the alternations of submarine and calcareous strata in the Val di Noto in Sicily*. In 1790 he also described similar phenomena in the Vicentin and in the Tyrol †. Montlosier also published, in 1788, an elegant and spirited essay on the volcanos of Auvergne, combining accurate local observations with comprehensive views. Notwithstanding this mass of evidence, the scholars of Werner were prepared to support his opinions to their utmost extent, maintaining, in the fulness of their faith, that even obsidian was an aqueous precipitate. As they were blinded by their veneration for the great teacher, they were impatient of opposition, and soon imbibed the spirit of a faction; and their opponents, the Vulcanists, were not long in becoming contaminated with the same intemperate zeal. Ridicule and irony were weapons more frequently employed than argument by the rival sects, till at last the controversy was carried on with

* Journ. de Phys., tom. xxv. p. 191. † Ib., tom. xxxvii. part ii. p. 200.

a degree of bitterness almost unprecedented in questions of physical science. Desmarest alone, who had long before provided ample materials for refuting such a theory, kept aloof from the strife, and whenever a zealous Neptunist wished to draw the old man into an argument, he was satisfied with replying, 'Go and see *.'

Hutton, 1788.—It would be contrary to all analogy, in matters of graver import, that a war should rage with such fury on the continent, and that the inhabitants of our island should not mingle in the affray. Although in England the personal influence of Werner was wanting to stimulate men to the defence of the weaker side of the question, they contrived to find good reason for espousing the Wernerian errors with great enthusiasm. In order to explain the peculiar motives which led many to enter, even with party feeling, into this contest, we must present the reader with a sketch of the views unfolded by Hutton, a contemporary of the Saxon geologist. That naturalist had been educated as a physician, but, declining the practice of medicine, he resolved, when young, to remain content with the small independence inherited from his father, and thenceforth to give his undivided attention to scientific pursuits. He resided at Edinburgh, where he enjoyed the society of many men of high attainments, who loved him for the simplicity of his manners and the sincerity of his character. His application was unwearied, and he made frequent tours through different parts of England and Scotland, acquiring considerable skill as a mineralogist, and constantly arriving at grand and comprehensive views in geology. He communicated the results of his observations unreservedly, and with the fearless spirit of one who was conscious that love of truth was the sole stimulus of all his exertions. When at length he had matured his views, he published, in 1788, his 'Theory of the Earth †,' and the same, afterwards more fully developed in a separate work, in 1795. This treatise was the first in which geology was declared to be in no way concerned about 'questions as

* Cuvier, Éloge de Desmarest.

† Ed. Phil. Trans., 1788.

to the origin of things;' the first in which an attempt was made to dispense entirely with all hypothetical causes, and to explain the former changes of the earth's crust, by reference exclusively to natural agents. Hutton laboured to give fixed principles to geology, as Newton had succeeded in doing to astronomy; but in the former science too little progress had been made towards furnishing the necessary data to enable any philosopher, however great his genius, to realize so noble a project.

Huttonian theory.—'The ruins of an older world,' said Hutton, 'are visible in the present structure of our planet, and the strata which now compose our continents have been once beneath the sea, and were formed out of the waste of pre-existing continents. The same forces are still destroying, by chemical decomposition or mechanical violence, even the hardest rocks, and transporting the materials to the sea, where they are spread out, and form strata analogous to those of more ancient date. Although loosely deposited along the bottom of the ocean, they become afterwards altered and consolidated by volcanic heat, and then heaved up, fractured and contorted.' Although Hutton had never explored any region of active volcanos, he had convinced himself that basalt and many other trap-rocks were of igneous origin, and that many of them had been injected in a melted state through fissures in the older strata. The compactness of these rocks, and their different aspect from that of ordinary lava, he attributed to their having cooled down under the pressure of the sea, and in order to remove the objections started against this theory, his friend Sir James Hall instituted a most curious and instructive series of chemical experiments, illustrating the crystalline arrangement and texture assumed by melted matter cooled down under high pressure.

The absence of stratification in granite, and its analogy in mineral character to rocks which he deemed of igneous origin, led Hutton to conclude that granite must also have been formed from matter in fusion, and this inference he felt could

not be fully confirmed, unless he discovered at the contact of granite and other strata a repetition of the phenomena exhibited so constantly by the trap-rocks. Resolved to try his theory by this test, he went to the Grampians and surveyed the line of junction of the granite and superincumbent stratified masses, and found in Glen Tilt in 1785 the most clear and unequivocal proofs in support of his views. Veins of red granite are there seen branching out from the principal mass, and traversing the black micaceous schist and primary limestone. The intersected stratified rocks are so distinct in colour and appearance as to render the example in that locality most striking, and the alteration of the limestone in contact was very analogous to that produced by trap veins on calcareous strata. This verification of his system filled him with delight, and called forth such marks of joy and exultation, that the guides who accompanied him, says his biographer, were convinced that he must have discovered a vein of silver or gold*. He was aware that the same theory would not explain the origin of the primary schists, but these he called primary, rejecting the term primitive, and was disposed to consider them as sedimentary rocks altered by heat, and that they originated in some other form from the waste of previously existing rocks.

By this important discovery of granite veins, to which he had been led by fair induction from an independent class of facts, Hutton prepared the way for the greatest innovation on the systems of his predecessors. Vallisneri had pointed out the general fact, that there were certain fundamental rocks which contained no organic remains, and which he supposed to have been formed before the creation of living beings. Moro, Generelli, and other Italian writers embraced the same doctrine, and Lehman regarded the mountains called by him primitive, as parts of the original nucleus of the globe. The same tenet was an article of faith in the school of Freyberg; and if any one ventured to doubt the possibility of our being enabled to carry back our researches to the creation of the present order of

* Playfair's Works, vol. iv., p. 75.

things, the granitic rocks were triumphantly appealed to. On them seemed written in legible characters, the memorable inscription

> Dinanzi a me non fur cose create
> Se non eterne,

and no small sensation was excited when Hutton seemed, with unhallowed hand, desirous to erase characters already regarded by many as sacred. 'In the economy of the world,' said the Scotch geologist, 'I can find no traces of a beginning, no prospect of an end;' and the declaration was the more startling when coupled with the doctrine, that all past changes on the globe had been brought about by the slow agency of existing causes. The imagination was first fatigued and overpowered by endeavouring to conceive the immensity of time required for the annihilation of whole continents by so insensible a process. Yet when the thoughts had wandered through these interminable periods, no resting place was assigned in the remotest distance. The oldest rocks were represented to be of a derivative nature, the last of an antecedent series, and that perhaps one of many pre-existing worlds. Such views of the immensity of past time, like those unfolded by the Newtonian philosophy in regard to space, were too vast to awaken ideas of sublimity unmixed with a painful sense of our incapacity to conceive a plan of such infinite extent. Worlds are seen beyond worlds immeasurably distant from each other, and, beyond them all, innumerable other systems are faintly traced on the confines of the visible universe.

The characteristic feature of the Huttonian theory was, as before hinted, the exclusion of all causes not supposed to belong to the present order of nature. Its greatest defect consisted in the undue influence attributed to subterranean heat, which was supposed necessary for the consolidation of all submarine deposits. Hutton made no step beyond Hooke, Moro, and Raspe, in pointing out in what manner the laws now governing earthquakes might bring about geological changes, if sufficient time be allowed. On the contrary, he seems to have fallen far

short of some of their views. He imagined that the continents were first gradually destroyed, and that when their ruins had furnished materials for new continents, they were upheaved by violent and paroxysmal convulsions. He therefore required alternate periods of disturbance and repose, and such he believed had been, and would for ever be, the course of nature.

Generelli, in his exposition of Moro's system, had made a far nearer approximation towards reconciling geological appearances with the state of nature as known to us; for while he agreed with Hutton, that the decay and reproduction of rocks were always in progress, proceeding with the utmost uniformity, the learned Carmelitan represented the repairs of mountains by elevation from below, to be effected by an equally constant and synchronous operation. Neither of these theories considered singly, satisfies all the conditions of the great problem, which a geologist, who rejects cosmological causes, is called upon to solve; but they probably contain together the germs of a perfect system. There can be no doubt, that periods of disturbance and repose have followed each other in succession in every region of the globe, but it may be equally true, that the energy of the subterranean movements has been always uniform as regards the *whole earth.* The force of earthquakes may for a cycle of years have been invariably confined, as it is now, to large but determinate spaces, and may then have gradually shifted its position, so that another region, which had for ages been at rest, became in its turn the grand theatre of action.

Playfair's illustrations of Hutton.—Although Hutton's knowledge of mineralogy and chemistry was considerable, he possessed but little information concerning organic remains. They merely served him as they did Werner to characterize certain strata, and to prove their marine origin. The theory of former revolutions in organic life was not yet fully recognized, and without this class of proofs in support of the antiquity of the globe, the indefinite periods demanded by the Huttonian hypothesis, appeared visionary to many, and some

who deemed the doctrine inconsistent with revealed truths, indulged very uncharitable suspicions of the motives of its author. They accused him of a deliberate design of reviving the heathen dogma of an 'eternal succession,' and of denying that this world ever had a beginning. Playfair, in the biography of his friend, has the following comment on this part of their theory :—'In the planetary motions, where geometry has carried the eye so far, both into the future and the past, we discover no mark either of the commencement or termination of the present order. It is unreasonable, indeed, to suppose that such marks should anywhere exist. The Author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction. He has not permitted in His works any symptom of infancy or of old age, or any sign by which we may estimate either their future or their past duration. *He may put an end, as he no doubt gave a beginning*, to the present system, at some determinate period of time; but we may rest assured that this great catastrophe will not be brought about by the laws now existing, and that it is not indicated by anything which we perceive *.'

The party feeling excited against the Huttonian doctrines, and the open disregard of candour and temper in the controversy, will hardly be credited by our readers, unless we recall to their recollection that the mind of the English public was at that time in a state of feverish excitement. A class of writers in France had been labouring industriously, for many years, to diminish the influence of the clergy, by sapping the foundation of the Christian faith, and their success, and the consequences of the Revolution, had alarmed the most resolute minds, while the imagination of the more timid was continually haunted by dread of innovation, as by the phantom of some fearful dream.

Voltaire.—Voltaire had used the modern discoveries in physics as one of the numerous weapons of attack and ridicule

* Playfair's Works, vol. iv. p. 55.

directed by him against the Scriptures. He found that the most popular systems of geology were accommodated to the sacred writings, and that much ingenuity had been employed to make every fact coincide exactly with the Mosaic account of the creation and deluge. It was, therefore, with no friendly feelings, that he contemplated the cultivators of geology in general, regarding the science as one which had been successfully enlisted by theologians as an ally in their cause *. He knew that the majority of those who were aware of the abundance of fossil shells in the interior of continents, were still persuaded that they were proofs of the universal deluge; and as the readiest way of shaking this article of faith, he endeavoured to inculcate scepticism, as to the real nature of such shells, and to recall from contempt the exploded dogma of the sixteenth century, that they were sports of nature. He also pretended that vegetable impressions were not those of real plants †. Yet he was perfectly convinced that the shells had really belonged to living testacea, as may be seen in his essay 'On the formation of Mountains ‡.' He would sometimes, in defiance of all consistency, shift his ground when addressing the vulgar; and admitting the true nature of the shells collected in the Alps, and other places, pretend that they were eastern species, which had fallen from the hats of pilgrims coming from Syria. The numerous essays written by him on geological subjects were all calculated to strengthen preju-

* In allusion to the theories of Burnet, Woodward, and other physico-theological writers, he declared that they were as fond of changes of scene on the face of the globe, as were the populace at a play. 'Every one of them destroys and renovates the earth after his own fashion, as Descartes framed it: for philosophers put themselves without ceremony in the place of God, and think to create a universe with a word.'—Dissertation envoyée à l'Académie de Bologne, sur les changemens arrivés dans notre Globe. Unfortunately this and similar ridicule directed against the cosmologists was too well deserved.

† See the chapter on 'Des pierres figurées.'

‡ In that essay he lays it down 'that all naturalists are now agreed that deposits of shells in the midst of the continents, are monuments of the continued occupation of these districts by the ocean.' In another place also, when speaking of the fossil shells of Touraine, he admits their true origin.

dices, partly because he was ignorant of the real state of the science, and partly from his bad faith*. On the other hand, they who knew that his attacks were directed by a desire to invalidate Scripture, and who were unacquainted with the true merits of the question, might well deem the old diluvian hypothesis incontrovertible, if Voltaire could adduce no better argument against it, than to deny the true nature of organic remains.

It is only by careful attention to impediments originating in extrinsic causes, that we can explain the slow and reluctant adoption of the simplest truths in geology. First, we find many able naturalists adducing the fossil remains of marine animals, as proofs of an event related in Scripture. The evidence is deemed conclusive by the multitude for a century or more; for it favours opinions which they entertained before, and they are gratified by supposing them confirmed by fresh and unexpected proofs. Many, who see through the fallacy, have no wish to undeceive those who are influenced by it, approving the effect of the delusion, and conniving at it as a pious fraud; until finally, an opposite party, who are hostile to the sacred writings, labour to explode the erroneous opinion, by substituting for it another dogma which they know to be equally unsound.

The heretical Vulcanists were now openly assailed in England, by imputations of the most illiberal kind. We cannot estimate the malevolence of such a persecution, by the pain which similar insinuations might now inflict; for although charges of infidelity and atheism must always be odious, they were injurious in the extreme at that moment of political excitement: and it was better perhaps for a man's good reception in society, that his moral character should have been traduced,

* As an instance of his desire to throw doubt indiscriminately on all geological data, we may recall the passage, where he says that 'the bones of a rein-deer and hippopotamus discovered near Etampes, did not prove, as some would have it, that Lapland and the Nile were once on a tour from Paris to Orleans, but merely that a lover of curiosities once preserved them in his cabinet.'

than that he should become a mark for these poisoned weapons. We shall pass over the works of numerous divines, who may be excused for sensitiveness on points which then excited so much uneasiness in the public mind; and we shall say nothing of the amiable poet Cowper *, who could hardly be expected to have inquired into the merits of doctrines in physics. But we find in the foremost ranks of the intolerant, several laymen who had high claims to scientific reputation. Among these, appears Williams, a mineral surveyor of Edinburgh, who published a 'Natural History of the Mineral Kingdom' in 1789, a work of great merit for that day, and of practical utility, as containing the best account of the coal strata. In his preface he misrepresents Hutton's theory altogether, and charges him with considering all rocks to be lavas of different colours and structure; and also with 'warping every thing to support the eternity of the world †.' He descants on the pernicious influence of such sceptical notions, as leading to downright infidelity and atheism, 'and as being nothing less than to depose the Almighty Creator of the universe from his office ‡.'

Kirwan, 1799.—Kirwan, president of the Royal Academy of Dublin, a chemist and mineralogist of some merit, but who possessed much greater authority in the scientific world than he was entitled by his talents to enjoy, in the introduction to his 'Geological Essays, 1799,' said 'that *sound* geology *graduated* into religion, and was required to dispel certain systems of atheism or infidelity, of which they had had recent experience §.' He was an uncompromising defender of the aqueous theory of all rocks, and was scarcely surpassed by Burnet and Whiston, in his desire to adduce the Mosaic writings in confirmation of his opinions.

De Luc.—De Luc, in the preliminary discourse to his Treatise on Geology ||, says, 'the weapons have been changed by which revealed religion is attacked; it is now assailed by geology, and this science has become essential to theologians.'

* The Task, book iii. 'The Garden.'

† P. 577. ‡ P. 59. § Introd. p. 2. || London, 1809.

He imputes the failure of former geological systems to their having been anti-mosaical, and directed against a 'sublime tradition.' These and similar imputations, reiterated in the works of De Luc, seem to have been taken for granted by some modern writers; it is therefore necessary to state, in justice to the numerous geologists of different nations, whose works we have considered, that none of them were guilty of endeavouring, by arguments drawn from physics, to invalidate scriptural tenets. On the contrary, the majority of them, who were fortunate enough 'to discover the true causes of things,' did not deserve another part of the poet's panegyric, '*Atque metus omnes subjecit pedibus.*' The caution, and even timid reserve, of many eminent Italian authors of the earlier period is very apparent; and there can hardly be a doubt that they subscribed to certain dogmas, and particularly to the first diluvian theory, out of deference to popular prejudices, rather than from conviction. If they were guilty of dissimulation, we must not blame their want of moral courage, but reserve our condemnation for the intolerance of the times, and that inquisitorial power which forced Galileo to abjure, and the two Jesuits to disclaim the theory of Newton *.

Playfair's defence of Hutton.—Hutton answered Kirwan's attacks with great warmth, and with the indignation excited by unmerited reproach. He had always displayed, says Play-

* I observe that, in a most able and interesting article, the 'Life of Galileo,' recently published in the 'Library of Useful Knowledge,' it is asserted that both Galileo's work, and the book of Copernicus 'Nisi corrigatur,' were still to be seen on the forbidden list of the Index at Rome in 1828. But I was assured in the same year, by Professor Scarpellini, at Rome, that Pius VII., a pontiff distinguished for his love of science, procured in 1818 a repeal of the edicts against Galileo and the Copernican system. He assembled the Congregation, and the late cardinal Toriozzi, assessor of the Sacred Office, proposed 'that they should wipe off this scandal from the church.' The repeal was carried, with the dissentient voice of one Dominican only. Long before this time the Newtonian theory had been taught in the Sapienza, and all Catholic universities in Europe (with the exception, I am told, of Salamanca); but it was always required of professors, in deference to the decrees of the church, to use the term *hypothesis*, instead of theory. They now speak of the Copernican *theory*.

fair, 'the utmost disposition to admire the beneficent design manifested in the structure of the world, and he contemplated with delight those parts of his theory which made the greatest additions to our knowledge of final causes.' We may say with equal truth, that in no scientific works in our language can more eloquent passages be found, concerning the fitness, harmony and grandeur of all parts of the creation, than in those of Playfair. They are evidently the unaffected expressions of a mind, which contemplated the study of nature, as best calculated to elevate our conceptions of the attributes of the First Cause. At any other time the force and elegance of Playfair's style must have insured popularity to the Huttonian doctrines; but, by a singular coincidence, neptunianism and orthodoxy were now associated in the same creed; and the tide of prejudice ran so strong, that the majority were carried far away into the chaotic fluid, and other cosmological inventions of Werner. These fictions the Saxon Professor had borrowed with little modification, and without any improvement, from his predecessors. They had not the smallest foundation, either in Scripture, or in common sense, but were perhaps approved of by many as being so ideal and unsubstantial, that they could never come into violent collision with any preconceived opinions.

The great object of De Luc's writings, which contained a valuable store of original observations in geology, was to disprove the high antiquity attributed by Hutton to our present continents, and particularly to seek out some cause for the excavation of valleys more speedy and violent than the action of ordinary rivers. Hutton had said that the erosion of rivers, and such floods as occur in the usual course of nature, might progressively, if time be allowed, hollow out great valleys, but he had also observed, 'that on our continents there is no spot on which a river may not formerly have run *.' De Luc generally reasoned against him as if he had said, that the exist-

* Theory of the Earth, vol. ii. p. 296; and Playfair's 'Illustrations,' note 16, p. 352.

ing rivers flowing *at their present levels* had caused all these inequalities of the earth's surface; and Playfair, in his zeal to prove how much De Luc underrated the force of running water, did not sufficiently expose his misstatement of the Huttonian proposition. But we must defer the full consideration of this controverted question for the present.

William Smith, 1790.—While the tenets of the rival schools of Freyberg and Edinburgh were warmly espoused by devoted partisans, the labours of an individual, unassisted by the advantages of wealth or station in society, were almost unheeded. Mr. William Smith, an English surveyor, published his 'Tabular View of the British Strata,' in 1790, wherein he proposed a classification of the secondary formations in the west of England. Although he had not communicated with Werner, it appeared by this work that he had arrived at the same views respecting the laws of superposition of stratified rocks; that he was aware that the order of succession of different groups was never inverted; and that they might be identified at very distant points by their peculiar organized fossils.

From the time of the appearance of the 'Tabular View,' he laboured to construct a geological map of the whole of England, and, with the greatest disinterestedness of mind, communicated the results of his investigations to all who desired information, giving such publicity to his original views, as to enable his contemporaries almost to compete with him in the race. The execution of his map was completed in 1815, and remains a lasting monument of original talent and extraordinary perseverance, for he had explored the whole country on foot without the guidance of previous observers, or the aid of fellow-labourers, and had succeeded in throwing into natural divisions the whole complicated series of British rocks *.

* Werner invented a new language to express his divisions of rocks, and some of his technical terms, such as grauwacke, gneiss, and others, passed current in every country in Europe. Smith adopted for the most part English provincial terms, often of barbarous sound, such as galt, cornbrash, clunch clay, &c., and affixed them to subdivisions of the British series. Many of these still retain their place in our scientific classifications, and attest his priority of arrangement.

D'Aubuisson, a distinguished pupil of Werner, paid a just tribute of praise to this remarkable performance, observing that 'what many celebrated mineralogists had only accomplished for a small part of Germany in the course of half a century, had been effected by a single individual for the whole of England.'

We have now arrived at the era of living authors, and shall bring to a conclusion our sketch of the progress of opinion in geology. The contention of the rival factions of the Vulcanists and Neptunists had been carried to such a height, that these names had become terms of reproach, and the two parties had been less occupied in searching for truth, than for such arguments as might strengthen their own cause, or serve to annoy their antagonists. A new school at last arose who professed the strictest neutrality, and the utmost indifference to the systems of Werner and Hutton, and who were resolved diligently to devote their labours to observation. The reaction, provoked by the intemperance of the conflicting parties, now produced a tendency to extreme caution. Speculative views were discountenanced, and through fear of exposing themselves to the suspicion of a bias towards the dogmas of a party, some geologists became anxious to entertain no opinion whatever on the causes of phenomena, and were inclined to scepticism even where the conclusions deducible from observed facts scarcely admitted of reasonable doubt.

Geological Society of London.—But although the reluctance to theorize was carried somewhat to excess, no measure could be more salutary at such a moment than a suspension of all attempts to form what were termed 'theories of the earth.' A great body of new data were required, and the Geological Society of London, founded in 1807, conduced greatly to the attainment of this desirable end. To multiply and record observations, and patiently to await the result at some future period, was the object proposed by them, and it was their favourite maxim that the time was not yet come for a general system of geology, but that all must be content for many years

to be exclusively engaged in furnishing materials for future generalizations. By acting up to these principles with consistency, they in a few years disarmed all prejudice, and rescued the science from the imputation of being a dangerous, or at best but a visionary pursuit.

MODERN PROGRESS OF GEOLOGY.

Study of organic remains.—Inquiries were at the same time prosecuted with great success by the French naturalists, who devoted their attention especially to the study of organic remains. They shewed that the specific characters of fossil shells and vertebrated animals might be determined with the utmost precision, and by their exertions a degree of accuracy was introduced into this department of science, of which it had never before been deemed susceptible. It was found that, by the careful discrimination of the fossil contents of strata, the contemporary origin of different groups could often be established, even where all identity of mineralogical character was wanting, and where no light could be derived from the order of superposition.

The minute investigation, moreover, of the relics of the animate creation of former ages, had a powerful effect in dispelling the illusion which had long prevailed concerning the absence of analogy between the ancient and modern state of our planet. A close comparison of the recent and fossil species, and the inferences drawn in regard to their habits, accustomed the geologist to contemplate the earth as having been at successive periods the dwelling-place of animals and plants of different races, some of which were discovered to have been terrestrial, and others aquatic—some fitted to live in seas, others in the waters of lakes and rivers. By the consideration of these topics, the mind was slowly and insensibly withdrawn from imaginary pictures of catastrophes and chaotic confusion, such as haunted the imagination of the early cosmogonists. Numerous proofs were discovered of the tranquil deposition of sedimentary matter and the slow development of organic life.

If many still continued to maintain, that 'the thread of induction was broken,' yet in reasoning by the strict rules of induction from recent to fossil species, they virtually disclaimed the dogma which in theory they professed. The adoption of the same generic, and, in some cases, even the same specific, names for the exuviæ of fossil animals, and their living analogues, was an important step towards familiarizing the mind with the idea of the identity and unity of the system in distant eras. It was an acknowledgment, as it were, that a considerable part of the ancient memorials of nature were written in a living language. The growing importance then of the natural history of organic remains, and its general application to geology, may be pointed out as the characteristic feature of the progress of the science during the present century. This branch of knowledge has already become an instrument of great power in the discovery of truths in geology, and is continuing daily to unfold new data for grand and enlarged views respecting the former changes of the earth.

When we compare the result of observations in the last thirty years with those of the three preceding centuries, we cannot but look forward with the most sanguine expectations to the degree of excellence to which geology may be carried, even by the labours of the present generation. Never, perhaps, did any science, with the exception of astronomy, unfold, in an equally brief period, so many novel and unexpected truths, and overturn so many preconceived opinions. The senses had for ages declared the earth to be at rest, until the astronomer taught that it was carried through space with inconceivable rapidity. In like manner was the surface of this planet regarded as having remained unaltered since its creation, until the geologist proved that it had been the theatre of reiterated change, and was still the subject of slow but never-ending fluctuations. The discovery of other systems in the boundless regions of space was the triumph of astronomy—to trace the same system through various transformations—to behold it at successive eras adorned with different hills and valleys, lakes

and seas, and peopled with new inhabitants, was the delightful meed of geological research. By the geometer were measured the regions of space, and the relative distances of the heavenly bodies—by the geologist myriads of ages were reckoned, not by arithmetical computation, but by a train of physical events—a succession of phenomena in the animate and inanimate worlds—signs which convey to our minds more definite ideas than figures can do, of the immensity of time.

Whether our investigation of the earth's history and structure will eventually be productive of as great practical benefits to mankind, as a knowledge of the distant heavens, must remain for the decision of posterity. It was not till astronomy had been enriched by the observations of many centuries, and had made its way against popular prejudices to the establishment of a sound theory, that its application to the useful arts was most conspicuous. The cultivation of geology began at a later period; and in every step which it has hitherto made towards sound theoretical principles, it has had to contend against more violent prepossessions. The practical advantages already derived from it have not been inconsiderable: but our generalizations are yet imperfect, and they who follow may be expected to reap the most valuable fruits of our labour. Meanwhile the charm of first discovery is our own, and as we explore this magnificent field of inquiry, the sentiment of a great historian of our times may continually be present to our minds, that 'he who calls what has vanished back again into being, enjoys a bliss like that of creating *.'

* Niebuhr's Hist. of Rome, vol. i. p. 5. Hare and Thirlwall's translation.

CHAPTER V.

Review of the causes which have retarded the progress of Geology—Effects of prepossessions in regard to the duration of past time—Of prejudices arising from our peculiar position as inhabitants of the land—Of those occasioned by our not seeing subterranean changes now in progress—All these causes combine to make the former course of Nature appear different from the present—Several objections to the assumption, that existing causes have produced the former changes of the earth's surface, removed by modern discoveries.

CAUSES WHICH HAVE RETARDED THE PROGRESS OF GEOLOGY.

We have seen that, during the progress of geology, there have been great fluctuations of opinion respecting the nature of the causes to which all former changes of the earth's surface are referrible. The first observers conceived that the monuments which the geologist endeavours to decipher relate to a period when the physical constitution of the earth differed entirely from the present, and that, even after the creation of living beings, there have been causes in action distinct in kind or degree from those now forming part of the economy of nature. These views have been gradually modified, and some of them entirely abandoned in proportion as observations have been multiplied, and the signs of former mutations more skilfully interpreted. Many appearances, which for a long time were regarded as indicating mysterious and extraordinary agency, are finally recognized as the necessary result of the laws now governing the material world; and the discovery of this unlooked for conformity has induced some geologists to infer that there has never been any interruption to the same uniform order of physical events. The same assemblage of general causes, they conceive, may have been sufficient to produce, by their various combinations, the endless diversity of effects, of which the shell of the earth has preserved the memorials, and,

consistently with these principles, the recurrence of analogous changes is expected by them in time to come.

Whether we coincide or not in this doctrine, we must admit that the gradual progress of opinion concerning the succession of phenomena in remote eras, resembles in a singular manner that which accompanies the growing intelligence of every people, in regard to the economy of nature in modern times. In an early stage of advancement, when a great number of natural appearances are unintelligible, an eclipse, an earthquake, a flood, or the approach of a comet, with many other occurrences afterwards found to belong to the regular course of events, are regarded as prodigies. The same delusion prevails as to moral phenomena, and many of these are ascribed to the intervention of demons, ghosts, witches, and other immaterial and supernatural agents. By degrees, many of the enigmas of the moral and physical world are explained, and, instead of being due to extrinsic and irregular causes, they are found to depend on fixed and invariable laws. The philosopher at last becomes convinced of the undeviating uniformity of secondary causes, and, guided by his faith in this principle, he determines the probability of accounts transmitted to him of former occurrences, and often rejects the fabulous tales of former times, on the ground of their being irreconcilable with the experience of more enlightened ages.

Prepossessions in regard to the duration of past time.—As a belief in the want of conformity in the physical constitution of the earth, in ancient and modern periods, was for a long time universally prevalent, and that too amongst men who were convinced that the order of nature is *now* uniform, and that it has continued so for several thousand years, every circumstance which could have influenced their minds and given an undue bias to their opinions deserves particular attention. Now the reader may easily satisfy himself, that, however undeviating the course of nature may have been from the earliest epochs, it was impossible for the first cultivators of geology to come to such a conclusion, so long as they were

under a delusion as to the age of the world, and the date of the first creation of animate beings. However fantastical some theories of the sixteenth century may now appear to us,—however unworthy of men of great talent and sound judgment, we may rest assured that, if the same misconceptions now prevailed in regard to the memorials of human transactions, it would give rise to a similar train of absurdities. Let us imagine, for example, that Champollion, and the French and Tuscan literati lately engaged in exploring the antiquities of Egypt, had visited that country with a firm belief that the banks of the Nile were never peopled by the human race before the beginning of the nineteenth century, and that their faith in this dogma was as difficult to shake as the opinion of our ancestors, that the earth was never the abode of living beings until the creation of the present continents, and of the species now existing,—it is easy to perceive what extravagant systems they would frame, while under the influence of this delusion, to account for the monuments discovered in Egypt. The sight of the pyramids, obelisks, colossal statues, and ruined temples, would fill them with such astonishment, that for a time they would be as men spell-bound—wholly incapable to reason with sobriety. They might incline at first to refer the construction of such stupendous works to some superhuman powers of a primeval world. A system might be invented resembling that so gravely advanced by Manetho, who relates that a dynasty of gods originally ruled in Egypt, of whom Vulcan, the first monarch, reigned nine thousand years. After them came Hercules and other demigods, who were at last succeeded by human kings.

When some fanciful speculations of this kind had amused the imagination for a time, some vast repository of mummies would be discovered, and would immediately undeceive those antiquaries who enjoyed an opportunity of personally examining them, but the prejudices of others at a distance, who were not eye-witnesses of the whole phenomena, would not be so easily overcome. The concurrent report of many travellers

would indeed render it necessary for them to accommodate ancient theories to some of the new facts, and much wit and ingenuity would be required to modify and defend their old positions. Each new invention would violate a greater number of known analogies; for if a theory be required to embrace some false principle, it becomes more visionary in proportion as facts are multiplied, as would be the case if geometers were now required to form an astronomical system on the assumption of the immobility of the earth.

Amongst other fanciful conjectures concerning the history of Egypt, we may suppose some of the following to be started. 'As the banks of the Nile have been so recently colonized for 'the first time, the curious substances called mummies could 'never in reality have belonged to men. They may have been 'generated by some *plastic virtue* residing in the interior of the 'earth, or they may be abortions of nature produced by her 'incipient efforts in the work of creation. For if deformed 'beings are sometimes born even now, when the scheme of the 'universe is fully developed, many more may have been "sent 'before their time, scarce half made up," when the planet itself 'was in the embryo state. But if these notions appear to de-'rogate from the perfection of the Divine attributes, and if 'these mummies be in all their parts true representations of 'the human form, may we not refer them to the future rather 'than the past? May we not be looking into the womb of 'Nature, and not her grave? May not these images be like 'the shades of the unborn in Virgil's Elysium—the archetypes 'of men not yet called into existence?'

These speculations, if advocated by eloquent writers, would not fail to attract many zealous votaries, for they would relieve men from the painful necessity of renouncing preconceived opinions. Incredible as such scepticism may appear, it would be rivalled by many systems of the sixteenth and seventeenth centuries, and among others by that of the learned Falloppio, who regarded the tusks of fossil elephants as earthy concretions, and the pottery or fragments of vases of Monte Testaceo,

near Rome, as works of nature, and not of art. But when one generation had passed away, and another not compromised to the support of antiquated dogmas had succeeded, they would review the evidence afforded by mummies more impartially, and would no longer controvert the preliminary question, that human beings had lived in Egypt before the nineteenth century: so that when a hundred years perhaps had been lost, the industry and talents of the philosopher would be at last directed to the elucidation of points of real historical importance.

But we have adverted to one only of many prejudices with which the earlier geologists had to contend. Even when they conceded that the earth had been peopled with animate beings at an earlier period than was at first supposed, they had no conception that the quantity of time bore so great a proportion to the historical era as is now generally conceded. How fatal every error as to the quantity of time must prove to the introduction of rational views concerning the state of things in former ages, may be conceived by supposing the annals of the civil and military transactions of a great nation to be perused under the impression that they occurred in a period of one hundred instead of two thousand years. Such a portion of history would immediately assume the air of a romance; the events would seem devoid of credibility and inconsistent with the present course of human affairs. A crowd of incidents would follow each other in thick succession. Armies and fleets would appear to be assembled only to be destroyed, and cities built merely to fall in ruins. There would be the most violent transitions from foreign or intestine war to periods of profound peace, and the works effected during the years of disorder or tranquillity would appear alike superhuman in magnitude.

He who should study the monuments of the natural world, under the influence of a similar infatuation, must draw a no less exaggerated picture of the energy and violence of causes, and must experience the same insurmountable difficulty in reconciling the former and present state of nature. If we could

behold in one view all the volcanic cones thrown up in Iceland, Italy, Sicily, and other parts of Europe, during the last five thousand years, and could see the lavas which have flowed during the same period; the dislocations, subsidences, and elevations caused by earthquakes; the lands added to various deltas, or devoured by the sea, together with the effects of devastation by floods, and imagine that all these events had happened in one year, we must form most exalted ideas of the activity of the agents, and the suddenness of the revolutions. Were an equal amount of change to pass before our eyes in the next year, could we avoid the conclusion that some great crisis of nature was at hand? If geologists, therefore, have misinterpreted the signs of a succession of events, so as to conclude that centuries were implied where the characters imported thousands of years, and thousands of years where the language of nature signified millions, they could not, if they reasoned logically from such false premises, come to any other conclusion, than that the system of the natural world had undergone a complete revolution.

We should be warranted in ascribing the erection of the great pyramid to superhuman power, if we were convinced that it was raised in one day; and if we imagine, in the same manner, a mountain-chain to have been elevated, during an equally small fraction of the time which was really occupied in upheaving it, we might then be justified in inferring, that the subterranean movements were once far more energetic than in our own times. We know that one earthquake may raise the coast of Chili for a hundred miles to the average height of about five feet. A repetition of two thousand shocks, of equal violence, might produce a mountain-chain one hundred miles long, and ten thousand feet high. Now, should one only of these convulsions happen in a century, it would be consistent with the order of events experienced by the Chilians from the earliest times; but if the whole of them were to occur in the next hundred years, the entire district must be depopulated, scarcely any animals or plants could survive, and the surface would be one confused heap of ruin and desolation.

One consequence of undervaluing greatly the quantity of past time, is the apparent coincidence which it occasions of events necessarily disconnected, or which are so unusual, that it would be inconsistent with all calculation of chances to suppose them to happen at one and the same time. When the unlooked-for association of such rare phenomena is witnessed in the present course of nature, it scarcely ever fails to excite a suspicion of the preternatural in those minds which are not firmly convinced of the uniform agency of secondary causes;—as if the death of some individual in whose fate they are interested, happens to be accompanied by the appearance of a luminous meteor, or a comet, or the shock of an earthquake. It would be only necessary to multiply such coincidences indefinitely, and the mind of every philosopher would be disturbed. Now it would be difficult to exaggerate the number of physical events, many of them most rare and unconnected in their nature, which were imagined by the Woodwardian hypothesis to have happened in the course of a few months; and numerous other examples might be found of popular geological theories, which require us to imagine that a long succession of events happened in a brief and almost momentary period.

The sources of prejudice hitherto considered may be deemed as in a great degree peculiar to the infancy of the science, but others are common to the first cultivators of geology and to ourselves, and are all singularly calculated to produce the same deception, and to strengthen our belief that the course of nature in the earlier ages differed widely from that now established. Although we cannot fully explain all these circumstances, without assuming some things as proved, which it will be the object of another part of this work to demonstrate, we must briefly allude to them in this place.

Prejudices arising from our peculiar position as inhabitants of the land.—The first and greatest difficulty, then, consists in our habitual unconsciousness that our position as observers is essentially unfavourable, when we endeavour to estimate the

magnitude of the changes now in progress. In consequence of our inattention to this subject, we are liable to the greatest mistakes in contrasting the present with former states of the globe. We inhabit about a fourth part of the surface; and that portion is almost exclusively the theatre of decay and not of reproduction. We know, indeed, that new deposits are annually formed in seas and lakes, and that every year some new igneous rocks are produced in the bowels of the earth, but we cannot watch the progress of their formation; and as they are only present to our minds by the aid of reflection, it requires an effort both of the reason and the imagination to appreciate duly their importance. It is, therefore, not surprising that we imperfectly estimate the result of operations invisible to us; and that, when analogous results of some former epoch are presented to our inspection, we cannot recognize the analogy. He who has observed the quarrying of stone from a rock, and has seen it shipped for some distant port, and then endeavours to conceive what kind of edifice will be raised by the materials, is in the same predicament as a geologist, who, while he is confined to the land, sees the decomposition of rocks, and the transportation of matter by rivers to the sea, and then endeavours to picture to himself the new strata which Nature is building beneath the waters.

Prejudices arising from our not seeing subterranean changes.—Nor is his position less unfavourable when, beholding a volcanic eruption, he tries to conceive what changes the column of lava has produced, in its passage upwards, on the intersected strata; or what form the melted matter may assume at great depths on cooling down; or what may be the extent of the subterranean rivers and reservoirs of liquid matter far beneath the surface. It should, therefore, be remembered, that the task imposed on those who study the earth's history requires no ordinary share of discretion, for we are precluded from collating the corresponding parts of a system existing at two different periods. If we were inhabitants of another element—if the great ocean were our domain, instead of the narrow limits

of the land, our difficulties would be considerably lessened; while, on the other hand, there can be little doubt, although the reader may, perhaps, smile at the bare suggestion of such an idea, that an amphibious being, who should possess our faculties, would still more easily arrive at sound theoretical opinions in geology, since he might behold, on the one hand, the decomposition of rocks in the atmosphere, and the transportation of matter by running water; and, on the other, examine the deposition of sediment in the sea, and the imbedding of animal remains in new strata. He might ascertain, by direct observation, the action of a mountain torrent, as well as of a marine current; might compare the products of volcanos on the land with those poured out beneath the waters; and might mark, on the one hand, the growth of the forest, and on the other that of the coral reef. Yet, even with these advantages, he would be liable to fall into the greatest errors when endeavouring to reason on rocks of subterranean origin. He would seek in vain, within the sphere of his observation, for any direct analogy to the process of their formation, and would therefore be in danger of attributing them, wherever they are upraised to view, to some 'primeval state of nature.'

But if we may be allowed so far to indulge the imagination, as to suppose a being, entirely confined to the nether world—some 'dusky melancholy sprite,' like Umbriel, who could 'flit on sooty pinions to the central earth,' but who was never permitted to 'sully the fair face of light,' and emerge into the regions of water and of air; and if this being should busy himself in investigating the structure of the globe, he might frame theories the exact converse of those usually adopted by human philosophers. He might infer that the stratified rocks, containing shells and other organic remains, were the oldest of created things, belonging to some original and nascent state of the planet. 'Of these masses,' he might say, 'whether they consist of loose incoherent sand, soft clay, or solid rock, none have been formed in modern times. Every year some part of them are broken and shattered by earthquakes, or melted up

by volcanic fire; and, when they cool down slowly from a state of fusion, they assume a crystalline form, perfectly distinct from their former inexplicable state, which are so regularly bedded, and contain stones full of curious impressions and fantastic markings. This process cannot have been carried on for an indefinite time, for in that case all the stratified rocks would long ere this have been fused and crystallized. It is therefore probable that the whole planet once consisted of these curiously-bedded formations, at a time when the volcanic fire had not yet been brought into activity. Since that period there seems to have been a gradual development of heat, and this augmentation we may expect to continue till the whole globe shall be in a state of fluidity and incandescence.'

Such might be the system of the Gnome at the very same time that the followers of Leibnitz, reasoning on what they saw on the outer surface, would be teaching the doctrine of gradual refrigeration, and averring that the earth had begun its career as a fiery comet, and would hereafter become a frozen icy mass. The tenets of the schools of the nether and of the upper world would be directly opposed to each other, for both would partake of the prejudices inevitably resulting from the continual contemplation of one class of phenomena to the exclusion of another. Man observes the annual decomposition of crystalline and igneous rocks, and may sometimes see their conversion into stratified deposits; but he cannot witness the reconversion of the sedimentary into the crystalline by subterranean fire. He is in the habit of regarding all the sedimentary rocks as more recent than the unstratified, for the same reason that we may suppose him to fall into the opposite error if he saw the origin of the igneous class only.

ASSUMPTION OF THE DISCORDANCE OF THE ANCIENT AND EXISTING CAUSES OF CHANGE UNPHILOSOPHICAL.

It is only by becoming sensible of our natural disadvantages that we shall be roused to exertion, and prompted to seek out opportunities of discovering the operations now in progress,

such as do not present themselves readily to view. We are called upon, in our researches into the state of the earth, as in our endeavours to comprehend the mechanism of the heavens, to invent means for overcoming the limited range of our vision. We are perpetually required to bring, as far as possible, within the sphere of observation, things to which the eye, unassisted by art, could never obtain access.

It was not an impossible contingency that astronomers might have been placed, at some period, in a situation much resembling that in which the geologist seems to stand at present. If the Italians, for example, in the early part of the twelfth century, had discovered at Amalphi, instead of the pandects of Justinian, some ancient manuscripts filled with astronomical observations relating to a period of three thousand years, and made by some ancient geometers who possessed optical instruments as perfect as any in modern Europe, they would probably, on consulting these memorials, have come to a conclusion that there had been a great revolution in the solar and sidereal systems. 'Many primary and secondary planets,' they might say, 'are enumerated in these tables, which exist no longer. Their positions are assigned with such precision, that we may assure ourselves that there is nothing in their place at present but the blue ether. Where one star is visible to us, these documents represent several thousands. Some of those which are now single, consisted then of two separate bodies, often distinguished by different colours, and revolving periodically round a common centre of gravity. There is no analogy to them in the universe at present, for they were neither fixed stars nor planets, but stood in the mutual relation of sun and planet to each other. We must conclude, therefore, that there has occurred, at no distant period, a tremendous catastrophe, whereby thousands of worlds have been annihilated at once, and some heavenly bodies absorbed into the substance of others.' When such doctrines had prevailed for ages, the discovery of one of the worlds, supposed to have been lost, by aid of the first rude telescope

invented after the revival of science, would not dissipate the delusion, for the whole burden of proof would now be thrown on those who insisted on the stability of the system from the beginning of time, and these philosophers would be required to demonstrate the existence of *all* the worlds said to have been annihilated.

Such popular prejudices would be most unfavourable to the advancement of astronomy; for, instead of persevering in the attempt to improve their instruments, and laboriously to make and record observations, the greater number would despair of verifying the continued existence of the heavenly bodies not visible to the nake eye. Instead of confessing the extent of their ignorance, and striving to remove it by bringing to light new facts, they would be engaged in the indolent employment of framing imaginary theories concerning catastrophes and mighty revolutions in the system of the universe.

For more than two centuries the shelly strata of the Sub-apennine hills afforded matter of speculation to the early geologists of Italy, and few of them had any suspicion that similar deposits were then forming in the neighbouring sea. They were as unconscious of the continued action of causes still producing similar effects, as the astronomers, in the case supposed by us, of the existence of certain heavenly bodies still giving and reflecting light, and performing their movements as in the olden time. Some imagined that the strata, so rich in organic remains, instead of being due to secondary agents, had been so created in the beginning of things by the fiat of the Almighty; and others ascribed the imbedded fossil bodies to some plastic power which resided in the earth in the early ages of the world. At length Donati explored the bed of the Adriatic, and found the closest resemblance between the new deposits there forming, and those which constituted hills above a thousand feet high in various parts of the peninsula. He ascertained that certain genera of living testacea were grouped together at the bottom of the sea in precisely the same manner as were their fossil analogues in the strata of the

hills, and that some species were common to the recent and fossil world. Beds of shells, moreover, in the Adriatic, were becoming incrusted with calcareous rock; and others were recently enclosed in deposits of sand and clay, precisely as fossil shells were found in the hills. This splendid discovery of the identity of modern and ancient submarine operations was not made without the aid of artificial instruments, which, like the telescope, brought phenomena into view not otherwise within the sphere of human observation.

In like manner, in the Vicentin, a great series of volcanic and marine sedimentary rocks were examined in the early part of the last century; but no geologist suspected, before the time of Arduino, that these were partly composed of ancient submarine lavas. If, when these enquiries were first made, geologists had been told that the mode of formation of such rocks might be fully elucidated by the study of processes then going on in certain parts of the Mediterranean, they would have been as incredulous as geometers would have been before the time of Newton, if any one had informed them that, by making experiments on the motion of bodies on the earth, they might discover the laws which regulated the movements of distant planets.

The establishment, from time to time, of numerous points of identification, drew at length from geologists a reluctant admission, that there was more correspondence between the physical constitution of the globe, and more uniformity in the laws regulating the changes of its surface, from the most remote eras to the present, than they at first imagined. If, in this state of the science, they still despaired of reconciling every class of geological phenomena to the operations of ordinary causes, even by straining analogy to the utmost limits of credibility, we might have expected, that the balance of probability at least would now have been presumed to incline towards the identity of the causes. But, after repeated experience of the failure of attempts to speculate on different classes of geological phenomena, as belonging to a distinct order of things, each new

sect persevered systematically in the principles adopted by their predecessors. They invariably began, as each new problem presented itself, whether relating to the animate or inanimate world, to assume in their theories, that the economy of nature was formerly governed by rules quite independent of those now established. Whether they endeavoured to account for the origin of certain igneous rocks, or to explain the forces which elevated hills or excavated valleys, or the causes which led to the extinction of certain races of animals, they first presupposed an original and dissimilar order of nature; and when at length they approximated, or entirely came round to an opposite opinion, it was always with the feeling, that they conceded what they were justified *à priori* in deeming improbable. In a word, the same men who, as natural philosophers, would have been greatly surprised to find any deviation from the usual course of Nature *in their own time*, were equally surprised, as geologists, not to find such deviations at every period of the past.

The Huttonians were conscious that no check could be given to the utmost licence of conjecture in speculating on the causes of geological phenomena, unless we can assume invariable constancy in the order of Nature. But when they asserted this uniformity without any limitation as to time, they were considered, by the majority of their contemporaries, to have been carried too far, especially as they applied the same principle to the laws of the organic, as well as of the inanimate world *.

We shall first advert briefly to many difficulties which formerly appeared insurmountable, but which, in the last forty years, have been partially or entirely removed by the progress of science; and shall afterwards consider the objections that still remain to the doctrine of absolute uniformity.

In the first place, it was necessary for the supporters of this doctrine to take for granted incalculable periods of time, in order to explain the formation of sedimentary strata by

* See a passage in the Illustrations of the Huttonian Theory, § 413, cited as the motto to the second volume of this work.

causes now in diurnal action. The time which they required theoretically, is now granted, as it were, or has become absolutely requisite, to account for another class of phenomena brought to light by more recent investigations. It must always have been evident to unbiassed minds, that successive strata, containing, in regular order of superposition, distinct beds of shells and corals, arranged in families as they grow at the bottom of the sea, could only have been formed by slow and insensible degrees in a great lapse of ages; yet, until organic remains were minutely examined and specifically determined, it was rarely possible to prove that the series of deposits met with in one country was not formed simultaneously with that found in another. But we are now able to determine, in numerous instances, the relative dates of sedimentary rocks in distant regions, and to show, by their organic remains, that they were not of contemporary origin, but formed in succession. We often find, that where an interruption in the consecutive formations in one district is indicated by a sudden transition from one assemblage of fossil species to another, the chasm is filled up, in some other district, by other important groups of strata.

The more attentively we study the European continent, the greater we find the extension of the whole series of geological formations. No sooner does the calendar appear to be completed, and the signs of a succession of physical events arranged in chronological order, than we are called upon to intercalate, as it were, some new periods of vast duration. A geologist, whose observations have been confined to England, is accustomed to consider the superior and newer groups of marine strata in our island as modern, and such they are, comparatively speaking; but when he has travelled through the Italian peninsula and in Sicily, and has seen strata of more recent origin forming mountains several thousand feet high, and has marked a long series both of volcanic and submarine operations, all newer than any of the regular strata which enter largely into the physical structure of Great Britain, he

returns with more exalted conceptions of the antiquity of some of our modern deposits, than he before entertained of the oldest of the British series.

We cannot reflect on the concessions thus extorted from us, in regard to the duration of past time, without foreseeing that the period may arrive when part of the Huttonian theory will be combated on the ground of its departing too far from the assumption of uniformity in the order of nature. On a closer investigation of extinct volcanos, we find proofs that they broke out at successive eras, and that the eruptions of one group were often concluded long before others had commenced their activity. Some were burning when one class of organic beings were in existence, others came into action when different races of animals and plants existed,—it follows, therefore, that the convulsions caused by subterranean movements, which are merely another portion of the volcanic phenomena, occurred also in succession, and their effects must be divided into separate sums, and assigned to separate periods of time; and this is not all: when we examine the volcanic products, whether they be lavas which flowed out under water or upon dry land, we find that intervals of time, often of great length, intervened between their formation, and that the effects of one eruption were not greater in amount than that which now results during ordinary volcanic convulsions. The accompanying or preceding earthquakes, therefore, may be considered to have been also successive, and to have been in like manner interrupted by intervals of time, and not to have exceeded in violence those now experienced in the ordinary course of nature.

Already, therefore, may we regard the doctrine of the sudden elevation of whole continents by paroxysmal eruptions as invalidated; and there was the greatest inconsistency in the adoption of such a tenet by the Huttonians, who were anxious to reconcile former changes to the present economy of the world. It was contrary to analogy to suppose, that Nature had been at any former epoch parsimonious of time and prodigal of violence—to imagine that one district was not at rest

while another was convulsed—that the disturbing forces were not kept under subjection, so as never to carry simultaneous havoc and desolation over the whole earth, or even over one great region. If it could have been shown, that a certain combination of circumstances would at some future period produce a crisis in the subterranean action, we should certainly have had no right to oppose our experience for the last three thousand years as an argument against the probability of such occurrences in past ages; but it is not pretended that such a combination can be foreseen.

In speculating on catastrophes by water, we may certainly anticipate great floods in future, and we may therefore presume that they have happened again and again in past times. The existence of enormous seas of fresh water, such as the North-American lakes, the largest of which is elevated more than six hundred feet above the level of the ocean, and is in parts twelve hundred feet deep, is alone sufficient to assure us, that the time will come, however distant, when a deluge will lay waste a considerable part of the American continent. No hypothetical agency is required to cause the sudden escape of the confined waters. Such changes of level, and opening of fissures, as have accompanied earthquakes since the commencement of the present century, or such excavation of ravines as the receding cataract of Niagara is now effecting, might breach the barriers. Notwithstanding, therefore, that we have not witnessed within the last three thousand years the devastation by deluge of a large continent, yet, as we may predict the future occurrence of such catastrophes, we are authorized to regard them as part of the present order of Nature, and they may be introduced into geological speculations respecting the past, provided we do not imagine them to have been more frequent or general than we expect them to be in time to come.

The great contrast in the aspect of the older and newer rocks, in their texture, structure, and in the derangement of the strata, appeared formerly one of the strongest grounds for presuming that the causes to which they owed their origin were

perfectly dissimilar from those now in operation. But this incongruity may now be regarded as the natural result of subsequent modifications, since the difference of relative age is demonstrated to have been so immense, that, however slow and insensible the change, it must have become important in the course of so many ages. In addition to volcanic heat, to which the Vulcanists formerly attributed too much influence, we must allow for the effect of mechanical pressure, of chemical affinity, of percolation by mineral waters, of permeation by elastic fluids, and the action, perhaps, of many other forces less understood, such as electricity and magnetism. In regard to the signs of upraising and sinking, of fracture and contortion in rocks, it is evident that newer strata cannot be shaken by earthquakes, unless the subjacent rocks are also affected; so that the contrast in the relative degree of disturbance in the more ancient and the newer strata, is one of many proofs that the convulsions have happened in different eras, and the fact confirms the uniformity of the action of subterranean forces, instead of their greater violence in the primeval ages.

Doctrine of Universal Formations.—The popular doctrine of universal formations, or the unlimited geographical extent of strata, distinguished by similar mineral characters, appeared for a long time to present insurmountable objections to the supposition, that the earth's crust had been formed by causes now acting. If it had merely been assumed, that rocks originating from fusion by subterranean fire presented in all parts of the globe a perfect correspondence in their mineral composition, the assumption would not have been extravagant; for, as the elementary substances that enter largely into the composition of rocks are few in number, they may be expected to arrange themselves invariably in the same forms, whenever the elementary particles are freely exposed to the action of chemical affinities. But when it was imagined that sedimentary mixtures, including animal and vegetable remains, and evidently formed in the beds of ancient seas, were of a homogeneous nature throughout a whole hemisphere, or even farther, the dogma

precluded at once all hope of recognizing the slightest analogy between the ancient and modern causes of decay and reproduction. For we know that existing rivers carry down from different mountain chains sediment of distinct colours and composition; where the chains are near the sea, coarse sand and gravel is swept in; where they are distant, the finest mud. We know, also, that the matter introduced by springs into lakes and seas is very diversified in mineral composition; in short, contemporaneous strata now in the progress of formation are greatly varied in their composition, and could never afford formations of homogeneous mineral ingredients co-extensive with the greater part of the earth's surface.

This theory, however, is in truth as inapplicable to the effects of those operations to which the formation of the earth's crust is due, as to the effects of existing causes. The first investigators of sedimentary rocks had never reflected on the great areas occupied by modern deltas of large rivers; still less on the much greater areas over which marine currents, preying alike on river-deltas, and continuous lines of sea-coast, diffuse homogeneous mixtures. They were ignorant of the vast spaces over which calcareous and other mineral springs abound upon the land and in the sea, especially in and near volcanic regions, and of the quantity of matter discharged by them. When, therefore, they ascertained the extent of the geographical distribution of certain groups of ancient strata—when they traced them continuously from one extremity of Europe to the other, and found them flanking, throughout their entire range, great mountain chains, they were astonished at so unexpected a discovery; and, considering themselves at liberty to disregard all modern analogy, they indulged in the sweeping generalization, that the law of continuity prevailed throughout strata of contemporaneous origin over the whole planet. The difficulty of dissipating this delusion was extreme, because some rocks, formed under similar circumstances at different epochs, present the same external characters, and often the same internal composition; and all these were assumed to be contemporaneous

until the contrary could be shown, which, in the absence of evidence derived from direct superposition, and in the scarcity of organic remains, was often impossible.

Innumerable other false generalizations have been derived from the same source; such, for instance, as the former universality of the ocean, now disproved by the discovery of the remains of terrestrial vegetation, contemporary with every successive race of marine animals; but we shall dwell no longer on exploded errors, but proceed at once to contend against weightier objections, which will require more attentive consideration.

CHAPTER VI.

Further examination of the question as to the discordance of the ancient and modern causes of change—Proofs that the climate of the Northern hemisphere was formerly hotter—Direct proofs from the organic remains of the Sicilian and Italian strata—Proofs from analogy derived from extinct Quadrupeds—Imbedding of Animals in Icebergs—Siberian Mammoths—Evidence in regard to temperature, from the fossil remains of tertiary and secondary rocks—From the Plants of the Coal formation.

FURTHER EXAMINATION OF THE QUESTION AS TO THE DISCORDANCE OF THE ANCIENT AND MODERN CAUSES OF CHANGE.

Climate of the Northern Hemisphere formerly hotter.—THAT the climate of the Northern hemisphere has undergone an important change, and that its mean annual temperature must once have resembled that now experienced within the tropics, was the opinion of some of the first naturalists who investigated the contents of ancient strata. Their conjecture became more probable when the shells and corals of the secondary rocks were more carefully examined, for these organic remains were found to be intimately connected by generic affinity with species now living in warmer latitudes. At a later period, many reptiles, such as turtles, tortoises, and large saurian animals, were discovered in the European strata in great abundance; and they supplied new and powerful arguments, from analogy, in support of the doctrine, that the heat of the climate had been great when our secondary formations were deposited. Lastly, when the botanist turned his attention to the specific determination of fossil plants, the evidence acquired the fullest confirmation, for the flora of a country is peculiarly influenced by temperature; and the ancient vegetation of the earth might, more readily than the forms of animals, have afforded conflicting proofs, had the popular theory been without foundation. When the examination of animal and vegetable remains was

extended to rocks in the most northern parts of Europe and North America, and even to the Arctic regions, indications of the same revolution in climate were discovered.

It cannot be said, that in this, as in many other departments of geology, we have investigated the phenomena of former eras, and neglected those of the present state of things. On the contrary, since the first agitation of this interesting question, the accessions to our knowledge of living animals and plants have been immense, and have far surpassed all the data previously obtained for generalizing, concerning the relation of certain types of organization to particular climates. The tropical and temperate zones of South America and of Australia have been explored; and, on close comparison, it has been found, that scarcely any of the species of the animate creation in these extensive continents are identical with those inhabiting the old world. Yet the zoologist and botanist, well acquainted with the geographical distribution of organic beings in other parts of the globe, would have been able, if distinct groups of species had been presented to them from these regions, to recognise those which had been collected from latitudes within, and those which were brought from without the tropics.

Before we attempt to explain the probable causes of great vicissitudes of temperature on the earth's surface, we shall take a rapid view of some of the principal data which appear to warrant, to the utmost extent, the popular opinions now entertained on the subject. To insist on the soundness of the inference, is the more necessary, because some zoologists have of late undertaken to vindicate the uniformity of the laws of nature, not by accounting for former fluctuations in climate, but by denying the value of the evidence on this subject *.

Direct proofs from the fossil remains of living species.—It is not merely by reasoning from analogy that we are led to infer a diminution of temperature in the climate of Europe; there

* See two articles by the Rev. Dr. Fleming, in the Edinburgh New Phil. Journ., No. xii. p. 277, April, 1829; and No. xv. p. 65, Jan. 1830.

are direct proofs in confirmation of the same doctrine, in the only countries hitherto investigated by expert geologists where we could expect to meet with direct proofs. It is not in England or Northern France, but around the borders of the Mediterranean, from the South of Spain to Calabria, and in the islands of the Mediterranean, that we must look for conclusive evidence on this question; for it is not in strata, where the organic remains belong to extinct species, but where living species abound in a fossil state, that a theory of climate can be subjected to the experimentum crucis. In Sicily, Ischia, and Calabria, where the fossil testacea of the more recent strata belong almost entirely to species now known to inhabit the Mediterranean, the conchologist remarks, that individuals in the inland deposits often exceed in their average size their living analogues, as if the circumstances under which they formerly lived had been more favourable to their development*. Yet no doubt can be entertained, on the ground of such difference in their dimensions, of their specific identity, because living individuals of many of these species still attain the average size of the fossils in warmer latitudes.

As we proceed northwards in the Italian peninsula, and pass from the region of active, to that of extinct volcanos—from districts now violently convulsed from time to time, to those which are comparatively undisturbed by earthquakes, we find the assemblage of fossil shells, in the modern (Subapennine) strata, to depart somewhat more widely from the type of the neighbouring seas. The proportion of species, identifiable

* I collected several hundred species of shells in Sicily, at different elevations, sometimes from one thousand to three thousand feet above the level of the sea, and forty species or more in Ischia, partly from an elevation of above one thousand feet, and these were carefully compared with recent shells procured by Professor O. G. Costa, from the Neapolitan seas. Not only were the fossil species for the most part identical with those now living, but the relative abundance in which different species occur in the strata and in the sea corresponds in a remarkable manner. Yet the larger average size of the fossil individuals of many species was very striking. A comparison of the fossil shells of the more modern strata of Calabria and Otranto, in the collection of Professor Costa, afforded similar results.

with those now living in the Mediterranean, is still considerable; but it no longer predominates, as in the South of Italy, over the unknown species. Although occurring in localities which are removed several degrees farther from the equator, (as at Sienna, Parma, Asti, &c.) the shells yield clear indications of a hotter climate. Many of them are common to the Subapennine hills, to the Mediterranean, and to the Indian Ocean. Those in the fossil state, and their living analogues from the tropics, correspond in size; whereas the individuals of the same species from the Mediterranean are dwarfish and degenerate, and stunted in their growth, for want of conditions which the Indian Ocean still supplies*.

This evidence amounts to demonstration, and is not neutralized by any facts of a conflicting character; such, for instance, as the association, in the same group, of individuals referrible to species now confined to arctic regions. On the contrary, whenever any of the fossil shells are identified with living species foreign to the Mediterranean, it is not in the Northern Ocean, but between the tropics, that they must be sought †.

* Professor Guidotti, of Parma, whose collection of Subapennine shells is unrivalled, and who has obtained from the North of Italy above twelve hundred species, showed me numerous suites of specimens in a fossil state, as well as from the Mediterranean and Indian seas, illustrating these views. Among other examples, the Bulla lignaria, a very common shell, is invariably found fossil of the same magnitude as it now reaches in the Indian sea, and much smaller in a living state in the Mediterranean. Individuals, however, of this great size are said to have been found at La Rochelle. The common Orthoceras of the Mediterranean, O. raphanista, attains larger average dimensions in a fossil, than in a recent state. Professor Bonelli, of Turin, who has above eight hundred species of shells from the Subapennines in the public museum, pointed out to me many examples, in confirmation of the same point.

† Thus, for example, Rostellaria curvirostris, found fossil by Signor Bonelli near Turin, is only known at present as an Indian shell. Murex cornutus, fossil at Asti, is now only known recent in warmer latitudes, the only localities given by Linnæus and Lamarck being the African and Great Indian Oceans. Senegal is the principal known habitat at present. Conus antediluvianus cannot be distinguished from a shell now brought from Owhyhee. Among other familiar instances mentioned to me by Italian naturalists, in confirmation of the same point, Buccinum clathratum, Lam., was cited; but Professor Costa assured me

On the other hand, the associated unknown species belong, for the most part, to genera which are now most largely developed in equinoctial regions, as, for example, the genera Pleurotoma and Cypræa *.

When we proceed to the central and northern parts of Europe, far from the modern theatres of volcanic action, and where there is no evidence of considerable inequalities of the earth's surface having been produced since the present species were in existence, our opportunities are necessarily more limited of procuring evidence from the contents of marine strata. It is only in lacustrine deposits, or in ancient river-beds, or in the sand and gravel of land-floods, or the stalagmite of ancient caverns once inhabited by wild beasts, that we can obtain access to proofs of the changes which animal life underwent during those periods when the marine strata already adverted to were deposited farther to the south. We often find, in such situations, the remains of extinct species of quadrupeds, such as the elephant, rhinoceros, hippopotamus, hyæna, and tiger, which belong to genera now confined to warmer regions.

It seems, therefore, fair to infer, that the same change of climate which has caused certain Indian species of testacea to become rare, or to degenerate in size, or to disappear from the Mediterranean,—and certain genera of the Subapennine hills, now exclusively tropical, to retain no longer any representatives in the adjoining seas,—may also have contributed to the annihilation of certain genera of land-mammifera, which inhabited the continents at about the same epoch. The mammoth (*Elephas primigenius*), and other extinct animals of the same era, may not have required the same temperature as their living

that this shell, although extremely rare, still occurs in the Mediterranean. M. Deshayes informs me that he has received it from the Indies.

* Of the genus Pleurotoma a very few living representatives have yet been found in the Mediterranean; yet no less than twenty-five species are now to be seen in the museum at Turin, all procured by Professor Bonelli from the Subapennine strata of northern Italy. The genus Cypræa is represented by many large fossil species in the Subapennine hills, with which are associated one small and two minute species of the same genus, now found in the Mediterranean.

congeners within the tropics; but we may infer that the climate was milder than that now experienced in some of the regions once inhabited by them, because, in Northern Russia, where their bones are found in immense numbers, it would be difficult, if not impossible, for such animals to obtain subsistence at present, during an arctic winter.

I fully agree with Dr. Fleming, that the kind of food which the existing species of elephant prefers will not enable us to determine, or even to offer a feasible conjecture, concerning that of the extinct species. No one, as he observes, acquainted with the gramineous character of the food of our fallow-deer, stag, or roe, would have assigned a lichen to the rein-deer. But, admitting that the trees and herbage on which the fossil elephants and rhinoceroses may have fed were not of a tropical character, but such perhaps as now grow in the temperate zone, it is still highly improbable that the vegetation which nourished these great quadrupeds was as scanty as that of our arctic regions, or that it was covered during the greater part of every year by snow.

It has been said, that as the modern northern animals migrate, the Siberian elephant may also have shifted his place during the inclemency of the season *; but this conjecture seems forced, even in regard to the elephant, and still more so when applied to the Siberian rhinoceros found in the frozen gravel of that country, as animals of this genus are heavy and slow in their motions, and can hardly be supposed to have accomplished great periodical migrations to southern latitudes. That the mammoth, however, continued for a long time to exist in Siberia after the winters had become extremely cold, is demonstrable, since their bones are found in icebergs, and in the frozen gravel, in such abundance as could only have been supplied by many successive generations. So many skeletons could not have belonged to herds which lived at one time in the district, even if those northern countries had once been

* Dr. Fleming, Edin. New Phil. Journ. No. xii. p. 285. April, 1829.

clothed with vegetation as luxuriant as that of an Indian jungle.

Tilesius, after giving an account of the immense quantity of mammoth's bones which have been procured from the frozen soil of Siberia, justly observes, that the number of elephants now living on the globe must be greatly inferior to those which occur fossil in those northern regions *.

But, if we suppose the change to have been extremely slow, and to have consisted, not so much in a diminution of the mean annual temperature as in an alteration from what has been termed an 'insular' to an 'excessive' climate,—from one in which the temperature of winter and summer were nearly equalized to one wherein the seasons were violently contrasted, —we may perhaps explain the phenomenon. Siberia and other arctic regions, after having possessed for ages a more uniform temperature, may, after certain changes in the form of the arctic land, have become occasionally exposed to extremely severe winters. When these first occurred at distant intervals, the drift snow would fill the valleys, and herds of herbivorous quadrupeds might be surprised and buried in a frozen mass, as often happens to cattle and human beings, overwhelmed in the Alpine valleys of Switzerland by avalanches. During a series of milder seasons intervening between the severe winters, the mammoths may have recovered their numbers, and the rhinoceroses may have multiplied again, so that the repetition of such catastrophes may have been indefinite. The increasing cold, and greater frequency of inclement winters, would at last thin their numbers, and their final extirpation would be consummated by the rapid augmentation of other herbivorous quadrupeds more fitted for the new climate.

That the greater part of the elephants lived in Siberia after it had become subject to intense cold, is confirmed, among other reasons, by the state of the ivory which has been so largely exported in commerce. Its perfect preservation indicates that, from the period when the individuals died, their remains were

* Memoirs of the Academy of St. Petersburgh, vol. v.

either buried in a frozen soil, or at least were not exposed to decay in a warm atmosphere. The same conclusion may be deduced from the clothing of the mammoth, of which the entire carcass was discovered by Mr. Adams on the shores of the frozen ocean, near the mouth of the river Lena, inclosed in a mass of ice. The skin of that individual was covered with long hair and with thick wool about an inch in length. Bishop Heber informs us, that along the lower range of the Himalaya mountains, in the north-eastern borders of the Delhi territory, between lat. 29° and 30°, he saw an Indian elephant covered with shaggy hair. In that region, where, within a short space, a nearly tropical and a cold climate meet, dogs and horses become covered, in the course of a winter or two, with shaggy hair, and many other species become, in as short a time, clothed with the same fine short shawl-wool which distinguishes the indigenous species of the country. Lions, tigers, and hyænas, are there found, with elks, chamois, and other species of genera usually abundant in colder latitudes *.

In regard to the imbedding of mammiferous remains in frozen mud and compact ice, we may observe that, besides the avalanches of snow above alluded to, deep crevices filled with drift snow traverse the glaciers of arctic regions, like the deep rents seen in the *mer de glace* on Mont Blanc. Thus in Spitzbergen, where bears, foxes, and deer abound, the snow collected in such icy fissures is described as being occasionally frozen over on the surface, and hard enough to bear a considerable weight. Dr. Latta relates that, while crossing a glacier in Spitzbergen, one of these treacherous bridges of snow gave way with him, so that he narrowly escaped being precipitated into the body of a glacier †. Dr. Richardson tells me that, in North America, about lat. 65°, he found the carcass of a deer which had fallen into a fissure in a rock, buried in snow, and the flesh, although the animal must have been dead three

* Narrative of a Journey through the Upper Provinces of India, vol. ii. p. 166—219.

† Edin. New Phil. Journ. No. v. p. 95, June, 1827.

months, had only become slightly putrescent. In fissures traversing a slippery glacier, these accidents must be frequent whenever herbivorous animals pass over them in their migrations, or hastily cross them when pursued by beasts of prey.

The conversion of drift snow into permanent glaciers and icebergs, when it happens to become covered over with alluvial matter transported by torrents and floods, is by no means a rare phenomenon in the arctic regions. Along the coast, in particular, E. and W. of the Mackenzie river, when the sea is frozen over, the snow drifted from the land forms a talus abutting against a perpendicular cliff. On the melting of the snow, torrents rush down from the land, charged with gravel and soil, and, falling over the edge of the cliff, cover the snow, which is often of considerable depth, with alluvium. Water, if any infiltration takes place, is frozen before it penetrates to the bottom of the mass, which is at last consolidated into a compact iceberg, protected from the heat of the sun by a covering of alluvium, on which vegetation often flourishes *.

Recent investigations have placed beyond all doubt the important fact that a species of tiger, identical with that of Bengal, is common in the neighbourhood of Lake Aral, near Sussac, in the forty-fifth degree of north latitude; and from time to time this animal is now seen in Siberia, in a latitude as far north as the parallel of Berlin and Hamburgh †. Humboldt remarks that the part of southern Asia now inhabited by this Indian species of tiger is separated from the Himalaya by two great chains of mountains, each covered with perpetual snow,—the chain of Kuenlun, N. lat. 35°, and that of Mouztagh, lat. 42°,—so that it is impossible that these animals should have merely made excursions from India, so as to have

* I am indebted to Dr. Richardson for this information, who has seen permanent glaciers forming in this manner in districts of North America now inhabited by many large herbivorous animals. The same process must evidently take place under river-cliffs, as well as along the sea-shore.

† Humboldt, Fragmens de Géologie, &c., tome ii. p. 388. Ehrenberg, Ann. des Sci. Nat., tome xxi. p. 387.

penetrated in summer to the forty-eighth and fifty-third degrees of north latitude. They must remain all the winter north of the Mouz-tagh, or Celestial Mountains. The last tiger killed in 1828 on the Lena, in lat. 52¼°, was in a climate colder than that of Petersburgh and Stockholm *.

A new species also of panther (*Felis irbis*), covered with long hair, has been discovered in Siberia, evidently inhabiting, like the tiger, a region north of the Celestial Mountains, which are in lat. 42° †.

These facts by no means invalidate the inference that the temperature of the northern hemisphere was warmer when the extinct species of elephant, rhinoceros, tiger, hyæna, and other genera, abounded in high latitudes, but they explain the occasional evidence which geology affords of certain individuals of these races having been enabled to survive down to comparatively modern times. A long series of ages may have intervened between the periods when such species were most flourishing and the era of their final extinction. The mammoth certainly appears to have survived in England when the temperature of our latitudes could not have been very different from that which now prevails; for remains of this animal have been found at North Cliff, in the county of York, in a lacustrine formation, in which all the land and freshwater shells, thirteen in number, can be identified with species and varieties now existing in that county. Bones of the bison also, an animal now inhabiting a cold or temperate climate, have been found in the same place. That these quadrupeds, and the indigenous species of testacea associated with them, were all contemporary inhabitants of Yorkshire, has been established by unequivocal proof. The Rev. W. V. Vernon Harcourt caused a pit to be sunk to the depth of twenty-two feet through undisturbed strata, in which the remains of the mammoth were found imbedded, together with the shells, in a deposit which had evidently resulted from tranquil waters ‡.

* Ehrenberg, Ann. des Sci. Nat., tome xxi. p. 390. † Ibid.

‡ Phil. Mag., Sept. 1829 and Jan. 1830.

Proofs from analogy of extinct species.—If we pass from the consideration of these more modern deposits, whether of marine or continental origin, in which existing species are intermixed with the extinct, to strata of somewhat higher antiquity (older tertiary strata, calcaire grossier, London clay, freshwater formations of Paris and Isle of Wight, &c.), we can only reason from analogy, since the species, whether of mammalia, reptiles, or testacea, are scarcely in any instance identifiable with any now in being *. In these strata, whether they were formed in seas or lakes, we find the remains of many animals analogous to those of hot climates, such as the crocodile, turtle, and tortoise, together with many large shells of the genus nautilus, and plants indicating such a temperature as is now found along the borders of the Mediterranean.

A great interval of time appears to have elapsed between the deposition of the last-mentioned (tertiary) strata, and the *secondary* formations, which constitute the principal portion of the more elevated land in Europe. In these secondary rocks a very distinct assemblage of organized fossils are entombed, all of unknown species, and many of them referrible to genera and families now most abundant between the tropics. Among the most remarkable are many gigantic reptiles, some of them herbivorous, others carnivorous, and far exceeding in size any now known even in the torrid zone. The genera are for the most part extinct, but some of them, as the crocodile and monitor, have still representatives in the warmer parts of the earth. Coral reefs also were evidently numerous in the seas of the same period, and composed of species belonging to genera now characteristic of a tropical climate. The number

* In the London clay, I believe, no recent species are yet discovered. But of twelve hundred species of shells, collected from the different fresh-water and marine formations of the Paris basin, M. Deshayes informs me, that there are some, but not much exceeding the proportion of three in a hundred, which he regards as perfectly identical with living species. Among these are Melanopsis buccinoides, from Epernais, now living in the Grecian archipelago, and Melania inquinata, now found between the tropics in the Philippine islands. Venus divaricata is not uncommon in the calcaire grossier at Grignon.

of immense chambered shells also leads us to infer an elevated temperature; and the associated fossil plants, although imperfectly known, tend to the same conclusion, the Cycadeæ constituting the most numerous family. But the study of the fossil flora of the coal deposits of still higher antiquity has yielded the most extraordinary evidence of an extremely hot climate, for it consisted almost exclusively of large vascular cryptogamic plants.

We learn, from the labours of M. Ad. Brongniart, that there existed at that epoch Equiseta upwards of ten feet high, and from five to six inches in diameter; tree ferns of from forty to fifty feet in height, and arborescent Lycopodiaceæ, of from sixty to seventy feet high *. Of the above classes of vegetables, the species are all small at present in cold climates; while in tropical regions there occur, together with small species, many of a much greater size, but their development at present, even in the hottest parts of the globe, is inferior to that indicated by the petrified forms of the coal formation. An elevated and uniform temperature, and great humidity in the air, are the causes most favourable for the numerical predominance and the great size of these plants within the torrid zone at present †.

* Consid. Générales sur la Nature de la Végétation, &c. Ann. des Sci. Nat. Nov. 1828.

† Humboldt, in speaking of the vegetation of the present era, considers the laws which govern the distribution of vegetable forms to be sufficiently constant to enable a botanist, who is informed of the number of one class of plants, to conjecture with tolerable accuracy the relative number of all others. It is premature, perhaps, to apply this law of proportion to the fossil botany of strata, between the coal formation and the chalk, as M. Adolphe Brongniart has attempted, as the number of species hitherto procured is so inconsiderable, that the quotient would be materially altered by the addition of one or two species. It may also be objected, that the fossil flora consists of such plants as may accidentally have been floated into seas, lakes, or estuaries, and may often, perhaps always, give a false representation of the numerical relations of families then living on the land. Yet, after allowing for all liability to error on these grounds, the argument founded on the comparative numbers of the fossil plants of the carboniferous strata is very strong.

Martius informs us that, on seeing the tesselated surface of the stems of arbo-

If the gigantic size and form of these fossil plants are remarkable, still more so is the extent of their geographical distribution; for impressions of arborescent ferns, such as characterize our English carboniferous strata, have been brought from Melville island, in latitude 75°.* The corals and chambered shells, which occur in beds interstratified with the coal (as in mountain limestone), afford also indications of a warm climate,—the gigantic orthocerata of this era being, to recent multilocular shells, what the fossil ferns, equiseta, and other plants of the coal strata, are in comparison with plants now growing within the tropics. These shells also, like the vegetable impressions, have been brought from rocks in very high latitudes in North America.

In vain should we attempt to explain away the phenomena of the carboniferous and other secondary formations, by supposing that the plants were drifted from equatorial seas. During the accumulation and consolidation of so many sedimentary deposits, and the various movements and dislocations to which they were subjected at different periods, rivers and currents must often have changed their direction, and wood might as often be floated from the arctic towards tropical seas, as in an opposite direction. It is undeniable, that the materials for future beds of lignite and coal are now amassed in high latitudes far from the districts where the forests grew, and on shores where scarcely a stunted shrub can now exist. The Mackenzie, and other rivers of North America, carry pines with their roots attached for many hundred miles towards the north, into the arctic sea, where they are imbedded in deltas, and some of them drifted still farther, by currents towards the pole. But such agency, although it might account for some partial anomalies in the admixture of vegetable remains of different climes, can by no means weaken the argu-

rescent ferns in Brazil, he was reminded of their prototypes in the impressions which he had seen in the coal-mines of Germany.

* Mr. Konig's description of the rocks brought home by Captain Parry, Journ. of Science, vol. xv. p. 20.

ments deduced from the general character of fossil vegetable remains.

We cannot suppose the leaves of tree ferns to be transported by water for thousands of miles, without being injured; nor, if this were possible, would the same hypothesis explain the presence of uninjured corals and multilocular shells of contemporary origin, for these must have lived in the same latitudes where they are now inclosed in rocks. The plants, moreover, whose remains have given rise to the coal beds, must be supposed to have grown upon the same land, the destruction of which provided materials for the sandstones and conglomerates of that group of strata. The coarseness of the particles of many of these rocks attests that they were not borne from very remote localities, but were most probably derived from islands in a vast sea, which was continuous, at that time, over a great part of the northern hemisphere, as is demonstrated by the great extent of the mountain and transition limestone formations.

The same observation is applicable to many secondary strata of a later epoch. There must have been dry land in these latitudes, to provide materials by its disintegration for sandstones,—to afford a beach whereon the oviparous reptiles deposited their eggs,—to furnish an habitation for the opossum of Stonesfield, and the insects of Solenhofen. The vegetation of the same lands, therefore, must in general have imparted to fossil floras their prevailing character.

From the considerations above enumerated, we must infer, that the remains both of the animal and vegetable kingdom preserved in strata of different ages, indicate that there has been a great diminution of temperature throughout the northern hemisphere, in the latitudes now occupied by Europe, Asia, and America. The change has extended to the arctic circle, as well as to the temperate zone. The heat and humidity of the air, and the uniformity of climate, appear to have been most remarkable when the oldest strata hitherto discovered were formed. The approximation to a climate similar

to that now enjoyed in these latitudes, does not commence till the era of the formations termed tertiary, and while the different tertiary rocks were deposited in succession, the temperature seems to have been still further lowered, and to have continued to diminish gradually, even after the appearance of a great portion of existing species upon the earth.

CHAPTER VII.

Further examination of the question as to the discordance of the ancient and modern causes of change—On the causes of vicissitudes in climate—Remarks on the present diffusion of heat over the globe—On the dependence of the mean temperature on the relative position of land and sea—Isothermal lines—Currents from equatorial regions—Drifting of icebergs—Different temperature of Northern and Southern hemispheres—Combination of causes which might produce the extreme cold of which the earth's surface is susceptible—On the conditions necessary for the production of the extreme of heat, and its probable effects on organic life.

Causes of vicissitudes in climate.—As the proofs enumerated in the last chapter indicate that the earth's surface has experienced great changes of climate since the deposition of the older sedimentary strata, we have next to inquire, how such vicissitudes can be reconciled with the existing order of nature. The cosmogonist has availed himself of this, as of every obscure problem in geology, to confirm his views concerning a period when the laws of the animate and inanimate world were wholly distinct from those now established; and he has in this, as in all other cases, succeeded so far, as to divert attention from that class of facts, which, if fully understood, might probably lead to an explanation of the phenomenon. At first, it was imagined that the earth's axis had been for ages perpendicular to the plane of the ecliptic, so that there was a perpetual equinox, and unity of seasons throughout the year;—that the planet enjoyed this '*paradisiacal*' state until the era of the great flood; but in that catastrophe, whether by the shock of a comet, or some other convulsion, it lost its equal poise, and hence the obliquity of its axis, and with that the varied seasons of the temperate zone, and the long nights and days of the polar circles.

When the advancement of astronomical science had exploded this theory, it was assumed, that the earth at its creation was in a state of fluidity, and red hot, and that ever

since that era it had been cooling down, contracting its dimensions, and acquiring a solid crust,—an hypothesis equally arbitrary, but more calculated for lasting popularity, because, by referring the mind directly to the beginning of things, it requires no support from observation, nor from any ulterior hypothesis. They who are satisfied with this solution are relieved from all necessity of inquiry into the present laws which regulate the diffusion of heat over the surface, for however well these may be ascertained, they cannot possibly afford a full and exact elucidation of the internal changes of an embryo world. As well might a naturalist, by merely studying the plumage and external forms of full-fledged birds, hope to divine the colour of their eggs, or the mysterious metamorphoses of the yolk during incubation.

But if, instead of vague conjectures as to what might have been the state of the planet at the era of its creation, we fix our thoughts steadily on the connexion at present between climate and the distribution of land and sea; and if we then consider what influence former fluctuations in the physical geography of the earth must have had on superficial temperature, we may perhaps approximate to a true theory. If doubt still remain, it should be ascribed to our ignorance of the laws of Nature, not to revolutions in her economy;—it should stimulate us to further research, not tempt us to indulge our fancies in framing imaginary systems for the government of infant worlds.

Laws governing the diffusion of heat over the globe.—In considering the laws which regulate the diffusion of heat over the globe, says Humboldt, we must beware not to regard the climate of Europe as a type of the temperature which all countries placed under the same latitudes enjoy. The physical sciences, observes this philosopher, always bear the impress of the places where they began to be cultivated; and, as in geology, an attempt was at first made to refer all the volcanic phenomena to those of the volcanos in Italy, so in meteorology, a small part of the old world, the centre of the primitive civilisation of Europe, was for a long time considered a type to which

the climate of all corresponding latitudes might be referred. But this region, constituting only one-seventh of the whole globe, proved eventually to be the exception to the general rule ; and for the same reason we may warn the geologist to be on his guard, and not hastily to assume that the temperature of the earth in the present era is a type of that which most usually obtains, since he contemplates far mightier alterations in the position of land and sea, at different epochs, than those which now cause the climate of Europe to differ from that of other countries in the same parallels.

It is now well ascertained that zones of equal warmth, both in the atmosphere and in the waters of the ocean, are neither parallel to the equator nor to each other*. It is also discovered that the same mean annual temperature may exist in two places which enjoy very different climates, for the seasons may be nearly equalized or violently contrasted. Thus the lines of equal winter temperature do not coincide with the lines of equal annual heat, or isothermal lines. The deviations of all these lines from the same parallel of latitude, are determined by a multitude of circumstances, among the principal of which are the position, direction, and elevation of the continents and islands, the position and depth of the sea, and the direction of currents and of winds.

It is necessary to go northwards in Europe in order to find the same mean quantity of annual heat as in a similar latitude in North America. On comparing these two continents, it is found that places situated in the same latitudes, have sometimes a mean difference of temperature amounting to 11°, or even sometimes 17°, of Fahrenheit; and places on the two continents, which have the same mean temperature, have sometimes a dif-

* We are indebted to Baron Alex. Humboldt for collecting together, in a beautiful essay, the scattered data on which some approximation to a true theory of the distribution of heat over the globe may be founded. Many of these data are derived from the author's own observations, and many from the works of M. Prevost on the radiation of heat, and other writers.—See Humboldt on Isothermal Lines, Mémoires d'Arcueil, tom. iii., translated in the Edin. Phil. Journ., vol. iii. July, 1820.

ference in latitude of from 7° to 13°.* The principal cause of greater intensity of cold in corresponding latitudes of North America and Europe, is the connexion of the former country with the polar circle, by a large tract of land, some of which is from three to five thousand feet in height, and, on the other hand, the separation of Europe from the arctic circle by an ocean. The ocean has a tendency to preserve every where a mean temperature, which it communicates to the contiguous land, so that it tempers the climate, moderating alike an excess of heat or cold. The elevated land, on the other hand, rising to the colder regions of the atmosphere, becomes a great reservoir of ice and snow, attracts, condenses, and congeals vapour, and communicates its cold to the adjoining country. For this reason, Greenland, forming part of a continent which stretches northward to the 82d degree of latitude, experiences under the 60th parallel a more rigorous climate than Lapland under the 72d parallel.

But if land be situated between the 40th parallel and the equator, it produces, unless it be of extreme height, exactly the opposite effect, for it then warms the tracts of land or sea that intervene between it and the polar circle. For the surface being in this case exposed to the vertical, or nearly vertical rays of the sun, absorbs a large quantity of heat, which it diffuses by radiation into the atmosphere. For this reason, the western parts of the old continent derive warmth from Africa, 'which, like an immense furnace,' says Malte-Brun †, 'distributes its heat to Arabia, to Turkey in Asia, and to Europe.' On the contrary, Asia, in its north-eastern extremity, experiences in the same latitude extreme cold, for it has land on the north between the 60th and 70th parallel, while to the south it is separated from the equator by the North Pacific.

In consequence of the more equal temperature of the waters of the ocean, the climate of islands and coasts differs essentially from that of the interior of continents, the former being cha-

* Humboldt's tables, Essay on Isothermal Lines, &c.

† Phys. Geog., book xvii.

racterized by mild winters and more temperate summers; for the sea breezes moderate the cold of winter, as well as the summer heat. When, therefore, we trace round the globe those belts in which the mean annual temperature is the same, we often find great differences in climate; for there are *insular* climates where the seasons are nearly equalized, and *excessive* climates, as they have been termed, where the temperature of winter and summer is strongly contrasted. The whole of Europe, compared with the eastern parts of America and Asia, has an insular climate. The northern part of China, and the Atlantic region of the United States, exhibit 'excessive climates.' We find at New York, says Humboldt, the summer of Rome and the winter of Copenhagen; at Quebec, the summer of Paris and the winter of Petersburgh. At Pekin, in China, where the mean temperature of the year is that of the coasts of Brittany, the scorching heats of summer are greater than at Cairo, and the winters as rigorous as at Upsal*.

If lines be drawn round the globe through all those places which have the same winter temperature, they are found to deviate from the terrestrial parallels much farther than the lines of equal mean annual heat. For the lines of equal winter in Europe are often curved so as to reach parallels of latitude 9° or 10° distant from each other, whereas the isothermal lines only differ from 4° to 5°.

Influence of currents on temperature.—Among other influential causes, both of remarkable diversity in the mean annual heat, and of unequal division of heat in the different seasons, are the direction of currents and the accumulation and drifting of ice in high latitudes. That most powerful current, the Gulf stream, after doubling the Cape of Good Hope, flows to the northward along the western coast of Africa, then crosses the Atlantic, and accumulates in the Gulf of Mexico. It then issues through the Straits of Bahama, running northwards at the rate of four miles an hour, and retains in the parallel of

* On Isothermal Lines.

38°, nearly one thousand miles from the above strait, a temperature 10° Fahrenheit warmer than the air.

The general climate of Europe is materially affected by the volume of warmer water thus borne northwards, for it maintains an open sea free from ice in the meridian of East Greenland and Spitzbergen, and thus moderates the cold of all the lands lying to the south. Until the waters of the great current reach the circumpolar sea, their specific gravity is less than that of the lower strata of water; but when they arrive near Spitzbergen, they meet with the water of melted ice which is still lighter, for it is a well-known law of this fluid, that it passes the point of greatest density when cooled down below 40°, and between that and the freezing point expands again. The warmer current, therefore, being now the heavier, sinks below the surface, so that in the lower regions it is found to be from 16° to 20° Fahrenheit, above the mean temperature of the climate. The movements of the sea, however, cause this undercurrent sometimes to appear at the surface, and greatly to moderate the cold *.

The great glaciers generated in the valleys of Spitzbergen, in the 79° of north latitude, are almost all cut off at the beach, being melted by the feeble remnant of heat retained by the Gulf stream. In Baffin's Bay, on the contrary, on the east coast of Old Greenland, where the temperature of the sea is not mitigated by the same cause, and where there is no warmer under-current, the glaciers stretch out from the shore, and furnish repeated crops of mountainous masses of ice which float off into the ocean †. The number and dimensions of these bergs is prodigious. Captain Ross saw several of them together in Baffin's Bay aground in water fifteen hundred feet deep! Many of them are driven down into Hudson's Bay, and, accumulating there, diffuse excessive cold over the neighbouring continent, so that Captain Franklin reports, that at

* Scoresby's Arctic Regions, vol. i. p. 210.

† Ibid. p. 208.—Dr. Latta's Observations on the Glaciers of Spitzbergen, &c. Edin. New Phil. Journ. vol. iii. p. 97.

the mouth of Hayes river, which lies in the same latitude as the north of Prussia or the south of Scotland, ice is found everywhere in digging wells, in summer, at the depth of four feet!

Difference of climate of the Northern and Southern hemispheres.—When we compare the climate of the northern and southern hemispheres, we obtain still more instruction in regard to the influence of the distribution of land and sea on climate. The dry land in the southern hemisphere is to that of the northern in the ratio only of one to three, excluding from our consideration that part which lies between the pole and the 74° of south latitude, which has hitherto proved inaccessible. The predominance of ice in the antarctic over the arctic zone is very great; for that which encircles the southern pole, extends to lower latitudes by ten degrees than that around the north pole *. It is probable that this remarkable difference is partly attributable, as Cook conjectured, to the existence of a considerable tract of high land between the 70th parallel of south latitude and the pole. There is, however, another reason suggested by Humboldt, to which great weight is due,—the small quantity of land in the tropical and temperate zones south of the line. If Africa and New Holland extended farther to the south, a diminution of ice would take place in consequence of radiation of the heat from these continents during summer, which would warm the contiguous sea and rarefy the air. The heated aërial currents would then ascend and flow more rapidly towards the south pole, and moderate the winter. In confirmation of these views, it is stated that the cap of ice,

* Captain Weddell, in 1823, reached 3° farther than Captain Cook, and arrived at 74° 15′ longitude, 34° 17′ west. After having passed through a sea strewed with numerous ice-islands, he arrived, in that high latitude, at an open ocean; but even if he had sailed 6° farther south, he would not have penetrated to higher latitudes than Captain Parry in the arctic circle, who reached lat. 81° 10′ north. The important discovery, therefore, of Captain Weddell, does not destroy the presumption, that the general prevalence of ice, in low latitudes in the southern hemisphere, arises from the existence of greater tracts of land in the antarctic, than in the arctic ocean.

which extends as far as the 68° and 71° of south latitude, advances more towards the equator whenever it meets a free sea; that is, wherever the extremities of the present continents are not opposite to it; and this circumstance seems explicable only on the principle above alluded to, of the radiation of heat from the lands so situated.

Before the amount of difference between the temperature of the two hemispheres was ascertained, it was referred by astronomers to the acceleration of the earth's motion in its perihelium; in consequence of which the spring and summer of the southern hemisphere are shorter, by nearly eight days, than those seasons north of the equator. A sensible effect is probably produced by this source of disturbance, but it is quite inadequate to explain the whole phenomenon. It is, however, of importance to the geologist to bear in mind, that in consequence of the precession of the equinoxes the two hemispheres receive alternately, each for a period of upwards of 10,000 years, a greater share of solar light and heat. This cause may sometimes tend to counterbalance inequalities resulting from other circumstances of a far more influential nature; but, on the other hand, it must sometimes tend to increase the extreme of deviation which certain combinations of causes produce at distant epochs.

But, whatever may now be the inferiority of heat in the temperate and arctic zones south of the line, it is quite evident that the cold would be far more intense if there happened, instead of open sea, to be tracts of elevated land between the 55th and 70th parallel; for, in Sandwich land, in 54° and 58° of south latitude, the perpetual snow and ice reach to the sea beach; and what is still more astonishing, in the island of Georgia, which is in the 53° south latitude, or the same parallel as the central counties of England, the perpetual snow descends to the level of the ocean. When we consider this fact, and then recollect that the highest mountains in Scotland do not attain the limit of perpetual snow on this side of the equator, we learn that latitude is one only of many powerful causes,

which determine the climate of particular regions of the globe. The permanence of snow in the southern hemisphere, in this instance, is partly due to the floating ice, which chills the atmosphere and condenses the vapour, so that in summer the sun cannot pierce through the foggy air.

The distance to which icebergs float from the polar regions on the opposite sides of the line is, as might have been anticipated, very different. Their extreme limit in the northern hemisphere appears to be the Azores (north latitude 42°), to which isles they are sometimes drifted from Baffin's Bay. But in the other hemisphere they have been seen, within the last two years, at different points off the Cape of Good Hope, between latitude 36° and 39°.* One of these was two miles n circumference, and 150 feet high †. Others rose from 250 to 300 feet above the level of the sea, and were therefore of great volume below, since it is ascertained, by experiments on the buoyancy of ice floating in sea-water, that for every solid foot seen above, there must at least be eight feet below water‡. If ice-islands from the north polar regions floated as far, they might reach Cape St. Vincent, and then, being drawn by the current that always sets in from the Atlantic through the Straits of Gibraltar, be drifted into the Mediterranean, so that the serene sky of that delightful region would immediately be deformed by clouds and mists.

The great extent of sea gives a particular character to climates south of the equator, the winters being mild and the summers cold. Thus, in Van Diemen's land, corresponding nearly in latitude to Rome, the winters are more mild than at Naples, and the summers not warmer than those at Paris, which is 7° farther from the equator §. The effect on vegetation is very remarkable:—tree ferns, for instance, which require

* On Icebergs in low Latitudes in the Southern Hemisphere, by Captain Horsburgh, Hydrographer to the East India Company; read to the Royal Society, February, 1830.

† Edin. New Phil. Journ., No. xv. p. 193; January, 1830.

‡ Scoresby's Arctic Regions, vol. i. p. 234. § Humboldt on Isothermal Lines.

abundance of moisture, and an equalization of the seasons, are found in Van Diemen's land in latitude 42°, and in New Zealand in south latitude 45°. The orchideous parasites also advance towards the 38° and 42° of south latitude. These forms of vegetation might perhaps be developed in still higher latitudes, if the ice in the antarctic circle did not extend farther from the pole than in the arctic. Humboldt observes that it is in the *mountainous, temperate, humid,* and *shady* parts of the equatorial regions, that the family of ferns produces the greatest number of species. As we know, therefore, that elevation often compensates the effect of latitude in plants, we may easily understand that a class of vegetables, which grow at a certain height in the torrid zone, would flourish on the plains far from the equator, provided the temperature, moisture, and other necessary conditions, were equally uniform throughout the year.

Changes in the position of land and sea may give rise to vicissitudes in climate.—Having offered these brief remarks on the diffusion of heat over the globe in the present state of the surface, we shall now proceed to speculate on the vicissitudes of climate, which must attend those endless variations in the geographical features of our planet which are contemplated in geology. In order to confine ourselves within the strict limits of analogy, we shall assume, 1st, That the proportion of dry land to sea continues always the same. 2dly, That the volume of the land rising above the level of the sea is a constant quantity; and not only that its mean, but that its extreme height, are only liable to trifling variations. 3dly, That both the mean and extreme depth of the sea are equal at every epoch; and, 4thly, It will be consistent with due caution to assume that the grouping together of the land in great continents is a necessary part of the economy of nature; for it is possible that the laws which govern the subterranean forces, and which act simultaneously along certain lines, cannot but produce, at every epoch, continuous mountain-chains; so that the sub-

division of the whole land into innumerable islands may be precluded.

If it be objected, that the maximum of elevation of land and depth of sea are probably not constant, nor the gathering together of all the land in certain parts, nor even perhaps the relative extent of land and water, we reply, that the arguments which we shall adduce will be greatly strengthened, if, in these peculiarities of the surface, there be considerable deviations from the present type. If, for example, all other circumstances being the same, the land is at one time more divided into islands than at another, a greater uniformity of climate might be produced, the mean temperature remaining unaltered; or if, at another era, there were mountains higher than the Himalaya, these, when placed in high latitudes, would cause a greater excess of cold. So, if we suppose that at certain periods no chain of hills in the world rose beyond the height of 10,000 feet, a greater heat might then have prevailed than is compatible with the existence of mountains thrice that elevation.

However constant we believe the relative proportion of sea and land to continue, we know that there is annually some small variation in their respective geographical positions, and that in every century the land is in some parts raised, and in others depressed by earthquakes, and so likewise is the bed of the sea. By these and other ceaseless changes, the configuration of the earth's surface has been remodelled again and again since it was the habitation of organic beings, and the bed of the ocean has been lifted up to the height of some of the loftiest mountains. The imagination is apt to take alarm when called upon to admit the formation of such irregularities of the crust of the earth, after it had become the habitation of living creatures; but if time be allowed, the operation need not subvert the ordinary repose of nature, and the result is insignificant if we consider how slightly the highest mountain-chains cause our globe to differ from a perfect sphere. Chimborazo, al-

though it rises to more than 21,000 feet above the surface of the sea, would only be represented, on an artificial globe of about six feet in diameter, by a grain of sand less than one-twentieth of an inch in thickness *.

The superficial inequalities of the earth, then, may be deemed minute in quantity, and their distribution at any particular epoch must be regarded in geology as temporary peculiarities, like the height and outline of the cone of Vesuvius in the interval between two eruptions. But, although the unevenness of the surface is so unimportant in reference to the magnitude of the globe, it is on the position and direction of these small inequalities that the state of the atmosphere and both the local and general climate are mainly dependent.

Before we consider the effect which a material change in the distribution of land and sea must occasion, it may be well to remark, how greatly organic life may be affected by those minor mutations, which need not in the least degree alter the general temperature. Thus, for example, if we suppose, by a series of convulsions, a certain part of Greenland to become sea, and, in compensation, a tract of land to rise and connect Spitzbergen with Lapland,—an accession not greater in amount than one which the geologist can prove to have occurred in certain districts bordering the Mediterranean, within a comparatively modern period,—this altered form of the land might occasion an interchange between the climate of certain parts of North America and of Europe, which lie in corresponding latitudes. Many European species would probably perish in consequence, because the mean temperature would be greatly lowered; and others would fail in America, because it would there be raised. On the other hand, in places where the mean annual heat remained unaltered, some species which flourish in Europe, where the seasons are more uniform, would be unable to resist the great heat of the North American summer, or the intense cold of the winter; while others, now fitted by their habits for the great contrast of the American seasons, would

* Malte-Brun's System of Geography, book i. p. 6.

not be fitted for the *insular* climate of Europe*. Many plants, for instance, will endure a severe frost, but cannot ripen their seeds without a certain intensity of summer-heat and a certain quantity of light; others cannot endure the same intensity of heat or cold.

It is now established that many species of animals, which are at present the contemporaries of man, have survived great changes in the physical geography of the globe. If such species be termed modern, in comparison to races which preceded them, their remains, nevertheless, enter into submarine deposits many hundred miles in length, and which have since been raised from the deep to no inconsiderable altitude. When, therefore, it is shewn that changes of the temperature of the atmosphere may be the consequence of such physical revolutions of the surface, we ought no longer to wonder that we find the distribution of existing species to be *local*, in regard to *longitude* as well as latitude. If all species were now, by an exertion of creative power, to be diffused uniformly throughout those zones where there is an equal degree of heat, and in all respects a similar climate, they would begin from this moment to depart more and more from their original distribution. Aquatic and terrestrial species would be displaced, as Hooke long ago observed, so often as land and water exchanged places; and there would also, by the formation of new mountains and other changes, be transpositions of climate, contributing, in the manner before alluded to, to the local extermination of species.

If we now proceed to consider the circumstances required for a *general* change of temperature, it will appear, from the facts and principles already laid down, that whenever a greater extent of high land is collected in the polar regions, the cold will augment; and the same result will be produced when there shall be more sea between or near the tropics; while, on the contrary, so often as the above conditions are reversed, the

* According to Humboldt, the vine can be cultivated with advantage 10° farther north in Europe than in North America.

heat will be greater. If this be admitted, it will follow as a corollary, that unless the superficial inequalities of the earth be fixed and permanent, there must be never-ending fluctuations in the mean temperature of every zone, and that the climate of one era can no more be a type of every other, than is one of our four seasons of all the rest.

It has been well said, that the earth is covered by an ocean, and in the midst of this ocean there are two great islands, and many smaller ones; for the whole of the continents and islands occupy an area scarcely exceeding one-fourth of the whole superficies of the spheroid. Now, on a fair calculation, we may expect that at any given epoch there will not be more than about one-fourth dry land in a particular region; such, for example, as the arctic and antarctic circles. If, therefore, at present there should happen in the only one of these regions which we can explore, to be much more than this average proportion of land, and some of it above five thousand feet in height, this alone affords ground for concluding that, in the present state of things, the mean heat of the climate is below that which the earth's surface, in its more ordinary state, would enjoy. This presumption is heightened, when we remember that the mean depth of the Atlantic ocean is calculated to be about three miles, and that of the Pacific four miles *; so that we might look not only for more than two-thirds sea in the frigid zones, but for water of great depth, which could not readily be reduced to the freezing point. The same opinion is further confirmed, when we compare the quantity of land lying between the poles and the 30th parallels of north and south latitude, and the quantity placed between those parallels and the equator; for it is clear, that at present we must have not only more than the usual degree of cold in the polar

* See Young's Nat. Phil. Lect. 47. Laplace seems often to have changed his opinion, reasoning from the depth required to account for the phenomena of the tides; but his final conclusion respecting the sea was 'que sa profondeur moyenne est du même ordre que la hauteur moyenne des continens et des îles au-dessus de son niveau, hauteur qui ne surpasse pas mille mètres (3280 ft.).' Mec. Céleste, Bk. 11. et Syst. du Monde, p. 254.

regions, but also less than the average quantity of heat generated in the intertropical zone.

Position of land and sea which might produce the extreme of cold of which the earth's surface is susceptible.—In order to simplify our view of the various changes in climate, which different combinations of geographical circumstances may produce, we shall first consider the conditions necessary for bringing about the extreme of cold, or what may be termed the winter of the 'great year,' or geological cycle, and afterwards, the conditions requisite for producing the maximum of heat, or the summer of the same year.

To begin with the northern hemisphere. Let us suppose those hills of the Italian peninsula and of Sicily, which are of comparatively modern origin, and contain many fossil shells identical with living species, to subside again into the sea, from which they have been raised, and that an extent of land of equal area and height (varying from one to three thousand feet) should rise up in the Arctic ocean between Siberia and the north pole. In speaking of such changes, we need not allude to the manner in which we conceive it possible that they may be brought about, nor of the time required for their accomplishment,—reserving for a future occasion, not only the proofs that revolutions of equal magnitude have taken place, but that analogous mutations are still in gradual progress. The alteration now supposed in the physical geography of the northern regions would cause additional snow and ice to accumulate where now there is usually an open sea; and the temperature of the greater part of Europe would be somewhat lowered, so as to resemble more nearly that of corresponding latitudes of North America; or, in other words, it might be necessary to travel about 10° farther south, in order to meet with the same climate which we now enjoy. There would be no compensation derived from the disappearance of land in the Mediterranean countries; for, on the contrary, the mean heat of the soil so situated, is probably far above that which would belong to the sea, by which we imagine it to be replaced.

But let the configuration of the surface be still further varied, and let some large district within or near the tropics, such as Mexico, for example, with its mountains rising to the height of twelve thousand feet and upwards, be converted into sea, while lands of equal elevation and extent are transferred to the arctic circle. From this change there would, in the first place, result a sensible diminution of temperature near the tropic, for the soil of Mexico would no longer be heated by the sun; so that the atmosphere would be less warm, as also the Atlantic, and the Gulf stream. On the other hand, the whole of Europe, Northern Asia, and North America, would feel the influence of the enormous quantity of ice and snow, now generated at vast heights on the new arctic continent. If, as we have already seen, there are some points in the southern hemisphere where snow is perpetual to the level of the sea, in latitudes as low as central England, such might now assuredly be the case throughout a great part of Europe. If at present the extreme limits of drifted icebergs are the Azores, they might easily reach the equator after the changes above supposed. To pursue the subject still farther, let the Himalaya mountains, with the whole of Hindostan, sink down, and their place be occupied by the Indian ocean, and then let an equal extent of territory and mountains, of the same vast height, stretch from North Greenland to the Orkney islands. It seems difficult to exaggerate the amount to which the climate of the northern hemisphere would now be cooled down.

But, notwithstanding the great refrigeration which would thus be produced, it is probable that the difference of mean temperature between the arctic and equatorial latitudes would not be increased in a very high ratio, for no great disturbance can be brought about in the climate of a particular region, without immediately affecting all other latitudes, however remote. The heat and cold which surround the globe are in a state of constant and universal flux and reflux. The heated and rarefied air is always rising and flowing from the equator towards the poles in the higher regions of the atmosphere, and,

in the lower, the colder air is flowing back to restore the equi librium. That this circulation is constantly going on in the aërial currents is not disputed; the fact, indeed, was illustrated in a striking manner by an event which happened in the present century. The trade wind continually blows with great force from the island of Barbadoes to that of St. Vincent's; notwithstanding which, during the eruption of the volcano in the Island of St. Vincent, in 1812, ashes fell in profusion from a great height in the atmosphere upon Barbadoes. This apparent transportation of matter against the wind, confirmed the opinion of the existence of a counter-current in the higher regions, which had previously rested on theoretical conclusions *.

That a corresponding interchange takes place in the seas, is demonstrated, according to Humboldt, by the cold which is found to exist at great depths between the tropics; and, among other proofs, may be mentioned the great volume of water which the Gulf stream is constantly bearing northwards, while another current flows *from* the north along the coast of Greenland and Labrador, and helps to restore the equilibrium †.

Currents of heavier and colder water pass from the poles towards the equator, which cool the inferior parts of the ocean; so that the heat of the torrid zone, and the cold of the polar circle balance each other. The refrigeration, therefore, of the polar regions, resulting from the supposed alteration in the distribution of land and sea, would be immediately communicated to the tropics, and from them would extend to the antarctic circle, where the atmosphere and the ocean would be cooled, so that ice and snow would augment. Although the mean temperature of higher latitudes in the southern hemi-

* Daniell's Meteorological Essays, &c., p. 103.

† In speaking of the circulation of air and water in this chapter, no allusion is made to the trade winds, or to irregularities in the direction of currents, caused by the rotatory motion of the earth. These causes prevent the movements from being direct from north to south, or from south to north, but they do not affect the theory of a constant circulation.

sphere is, as we have stated, for the most part lower than that of the same parallels in the northern, yet for a considerable space on each side of the line, the mean annual heat of the waters is found to be the same in corresponding parallels. When, therefore, by the new position of the land, the generating of icebergs had become of frequent occurrence in the northern temperate zone, and when they were frequently drifted as far as the equator, the same degree of cold would immediately be communicated as far as the tropic of Capricorn, and from thence to the lands or ocean to the south.

The freedom, then, of the circulation of heat and cold from pole to pole being duly considered, it will be evident that the mean quantity of solar heat which at two different periods visits the same point, may differ far more widely than the mean quantity which any two points receive in the same parallels of latitude, at one and the same period. For the range of temperature in a given zone, or in other words, the curves of the isothermal lines, must always be circumscribed within narrow limits, the climate of each place in that zone being controlled by the combined influence of the geographical peculiarities of all other parts of the earth. Whereas, if we compare the state of things as existing at two distinct epochs, a particular zone may at one time be under the influence of one class of disturbing causes, as for example those of a refrigerating nature, and at another time may be affected by a combination of opposite circumstances. The lands to the north of Greenland cause the present climate of North America to be colder than that of Europe in the same latitudes, but they also affect, to a certain extent, the temperature of the atmosphere in Europe; and the entire removal from the northern hemisphere of that great source of refrigeration would not assimilate the mean temperature of America to that now experienced in Europe, but would render the continents on both sides of the Atlantic much warmer.

To return to the state of the earth after the changes before supposed by us, we must not omit to dwell on the important

effects to which a wide expanse of perpetual snow would give rise. It is probable that nearly the whole sea, from the poles to the parallels of 45°, would be frozen over, for it is well known that the immediate proximity of land is not essential to the formation and increase of field ice, provided there be in some part of the same zone a sufficient quantity of glaciers generated on or near the land, to cool down the sea. Captain Scoresby, in his account of the arctic regions, observes, that when the sun's rays 'fall upon the snow-clad surface of the ice or land, they are in a great measure reflected, without producing any material elevation of temperature; but when they impinge on the black exterior of a ship, the pitch on one side occasionally becomes fluid, while ice is rapidly generated at the other *.'

Now field ice is almost always covered with snow †, and thus not only land as extensive as our existing continents, but immense tracts of sea in the frigid and temperate zones, might present a solid surface covered with snow, and reflecting the sun's rays for the greater part of the year. Within the tropics, moreover, where we suppose the ocean to predominate, the sky would no longer be serene and clear, as in the present era; but the melting of floating ice would cause quick condensations of vapour, and fogs and clouds would deprive the vertical rays of the sun of half their power. The whole planet, therefore, would receive annually a smaller proportion of solar influence, and the external crust would part, by radiation, with some of the heat which had been accumulated in it, during a different state of the surface. This heat would be dissipated into the spaces surrounding our atmosphere, which, according to the calculations of M. Fourier, have a temperature much inferior to that of freezing water.

At this period, the climate of equinoctial lands might resemble that of the present temperate zone, or perhaps be far more wintery. They who should then inhabit such small isles and coral reefs, as are now seen in the Indian ocean and South

* See Scoresby's Arctic Regions, vol. i. p. 378. † Ib. p. 320.

Pacific, would wonder that zoophytes of such large dimensions had once been so prolific in those seas; or if, perchance, they found the wood and fruit of the cocoa-nut tree or the palm silicified by the waters of some ancient mineral spring, or incrusted with calcareous matter, they would muse on the revolutions that had annihilated such genera, and replaced them by the oak, the chestnut, and the pine. With equal admiration would they compare the skeletons of their small lizards with the bones of fossil alligators and crocodiles more than twenty feet in length, which, at a former epoch, had multiplied between the tropics; and when they saw a pine included in an iceberg, drifted from latitudes which we now call temperate, they would be astonished at the proof thus afforded, that forests had once grown where nothing could be seen in their own times but a wilderness of snow.

As we have not yet supposed any mutations to have taken place in the relative position of land and sea in the southern hemisphere, we might still increase greatly the intensity of cold, by transferring the land still remaining in the equatorial and contiguous regions, to higher southern latitudes; but it is unnecessary to pursue the subject farther, as we are too ignorant of the laws governing the direction of subterranean forces, to determine whether such a crisis be within the limits of possibility. At the same time we may observe, that the distribution of land at present is so remarkably irregular, and appears so capricious, if we may so express ourselves, that the two extremes of terrestrial heat and cold are probably separated very widely from each other. The globe may now be equally divided, so that one hemisphere shall be entirely covered with water, with the exception of some promontories and islands, while the other shall contain less water than land; and what is still more extraordinary, on comparing the extra-tropical lands in the northern and southern hemispheres, the former are found to be to the latter in the proportion of thirteen to one*! To imagine all the lands, therefore, in high,

* Humboldt, on Isothermal Lines.

and all the sea in low latitudes, would scarcely be a more anomalous state of the surface.

Position of land and sea which might give rise to the extreme of heat.—Let us now turn from the contemplation of the winter of the 'great year,' and consider the opposite train of circumstances, which would bring on the spring and summer. That some part of the vast ocean which forms the Atlantic and Pacific, should at certain periods occupy entirely one or both of the polar regions, and should extend, interspersed with islands only, to the parallels of 40°, and even 30°, is an event that may be supposed in the highest degree probable, in the course of many great geological revolutions. In order to estimate the degree to which the general temperature would then be elevated, we should begin by considering separately the effect of the diminution of certain portions of land, in high northern latitudes, which might cause the sea to be as open in every direction, as it is at present towards the north pole, in the meridian of Spitzbergen. By transferring the same lands to the torrid zone, we might gain farther accessions of heat, and cause the ice towards the south pole to diminish. We might first continue these geographical mutations, until we had produced as mild a climate in high latitudes as exists at those points in the same parallel where the mean annual heat is now greatest. We should then endeavour to calculate what further alterations would be required to double the amount of change; and the great deviation of isothermal lines at present seems to authorize us to infer, that without an entire revolution of the surface, we might cause the mean temperature to vary to an extent equivalent to 20° or even 30° of latitude,—in other words, we might transfer the temperature of the torrid zone, to the mean parallel, and of the latter, to the arctic regions. By additional transpositions, therefore, of land and sea, we might bring about a still greater variation, so that, throughout the year, all signs of frost should disappear from the earth.

The plane of congelation would rise in the atmosphere in all latitudes; and as our hypothesis would place all the highest

mountains in the torrid zone, they would be clothed with rich vegetation to their summits. We must recollect that even now it is necessary to ascend to the height of 15,000 feet in the Andes under the line, and in the Himalaya mountains, which are without the tropic, to 17,000 feet, before we reach the limit of perpetual snow. When the absorption of the solar rays was unimpeded, even in winter, by a coat of snow, the mean heat of the earth's crust would augment to considerable depths, and springs, which we know to be an index of the mean temperature of the climate, would be warmer in all latitudes. The waters of lakes, therefore, and rivers, would be much hotter in winter, and would be never chilled in summer by the melting of snow. A remarkable uniformity of climate would prevail amid the numerous archipelagos of the polar ocean, amongst which the tepid waters of equatorial currents would freely circulate. The general humidity of the atmosphere would far exceed that of the present period, for increased heat would promote evaporation in all parts of the globe. The winds would be first heated in their passage over the tropical plains, and would then gather moisture from the surface of the deep, till, charged with vapour, they would arrive at northern regions, and, encountering a cooler atmosphere, would discharge their burden in warm rain. If, during the long night of a polar winter, the snows should whiten the summit of some arctic islands, and ice collect in the bays of the remotest Thule, they would be dissolved as rapidly by the returning sun, as are the snows of Etna by the blasts of the sirocco.

We learn from those who have studied the geographical distribution of plants, that in very low latitudes, at present, the vegetation of small islands remote from continents has a peculiar character, and the ferns and allied families, in particular, bear a great proportion to the total number of other vegetables. Other circumstances being the same, the more remote the isles are from the continents, the greater does this proportion become. Thus, in the continent of India, and the tropical parts of New Holland, the proportion of ferns to the phanerogamic

plants is only as one to twenty-six; whereas, in the South-Sea Islands, it is as one to four, or even as one to three *. We might expect, therefore, in the summer of the 'great year,' which we are now considering, that there would be a great predominance of tree-ferns and plants allied to palms and arborescent grasses in the isles of the wide ocean, while the dicotyledonous plants and other forms now most common in temperate regions would almost disappear from the earth. Then might those genera of animals return, of which the memorials are preserved in the ancient rocks of our continents. The huge iguanodon might reappear in the woods, and the ichthyosaur in the sea, while the pterodactyle might flit again through umbrageous groves of tree-ferns. Coral reefs might be prolonged beyond the arctic circle, where the whale and the narwal now abound. Turtles might deposit their eggs in the sand of the sea-beach, where now the walrus sleeps, and where the seal is drifted on the ice-floe.

But, not to indulge these speculations farther, we may observe, in conclusion, that however great, in the lapse of ages, may be the vicissitudes of temperature in every zone, it accords with our theory that the general climate should not experience any sensible change in the course of a few thousand years, because that period is insufficient to affect the leading features of the physical geography of the globe. Notwithstanding the apparent uncertainty of the seasons, it is found that the mean temperature of particular localities is very constant, provided we compare observations made at different periods for a series of years.

Yet, there must be exceptions to this rule, and even the labours of man have, by the drainage of lakes and marshes, and the felling of extensive forests, caused such changes in the atmosphere as raise our conception of the more important influence of those forces to which even the existence, in certain latitudes, of land or water, hill or valley, lake or sea, must be

* Ad. Brongniart, Consid. Générales sur la Nat. de la Végét., &c. Ann. des Sciences Nat., Nov. 1828.

ascribed. If we possessed accurate information of the amount of local fluctuation in climate in the course of twenty centuries, it would often, undoubtedly, be considerable. Certain tracts, for example, on the coast of Holland and of England, consisted of cultivated land in the time of the Romans, which the sea, by gradual encroachments, has at length occupied. Here an alteration has been effected; for neither the division of heat in the different seasons, nor the mean annual heat of the atmosphere investing the sea is precisely the same as that which rests on the land.

In those countries also where the earthquake and volcano are in full activity, a much shorter period may produce a sensible variation. The climate of the once fertile plain of Malpais in Mexico must differ materially from that which prevailed before the middle of the last century; for, since that time, six mountains, the highest of them rising 1600 feet above the plateau, have been thrown up by volcanic eruptions. It is by the repetition of an indefinite number of local revolutions due to volcanic and various other causes, that a general change of climate is finally brought about.

CHAPTER VIII.

Further examination of the question as to the discordance of the ancient and modern causes of change—That the geographical features of the northern hemisphere, at the period of the deposition of the carboniferous strata, were such as might, according to the theory before explained, have given rise to an extremely hot climate—State of the surface when the transition and mountain limestones, coal-sandstones, and coal originated—Change in the physical geography of northern latitudes, between the era of the formation of the carboniferous series and the lias—Character of organic remains, from the lias to the chalk inclusive—State of the surface when these deposits originated—Great accession of land, and elevation of mountain-chains, between the consolidation of the newer secondary and older tertiary rocks—Consequent refrigeration of climate—Abrupt transition from the organic remains of the secondary to those of the tertiary strata—Maestricht beds—Remarks on the theory of the diminution of central heat.

That the geographical features of the northern hemisphere at the period of the deposition of the carboniferous strata were such as might have given rise to an extremely hot climate.— We stated, in the sixth chapter, our reasons for concluding that the mean annual temperature of the northern hemisphere was considerably more elevated when the old carboniferous strata were deposited; as also that the climate had been modified more than once since that epoch, and that it approximated by successive changes more and more nearly to that now prevailing in the same latitudes. Further, we endeavoured, in the last chapter, to prove that vicissitudes in climate of no less importance may be expected to recur in future, if it be admitted that causes now active in nature have power, in the lapse of ages, to vary to an unlimited extent the relative position of land and sea. It next remains for us to inquire whether the alterations, which the geologist can prove to have actually taken place at former periods, in the geographical features of the northern hemisphere, coincide in their nature, and in the time of their occurrence, with such revolutions in climate as

would naturally have followed, according to the meteorological principles already explained.

We may select the great carboniferous series, including the transition and mountain limestones, and the coal, as the oldest system of rocks of which the organic remains furnish any decisive evidence as to climate. We have already insisted on the indications which they afford of great heat and uniformity of temperature, extending over a vast area, from about 45° to 60°, or, perhaps, if we include Melville Island, to near 75° north latitude *.

When we attempt to restore in imagination the distribution of land and sea, as they existed at that remote epoch, we discover that our information is at present limited to latitudes north of the tropic of cancer, and we can only hope, therefore, to point out that the condition of the earth, so far as relates to our temperate and arctic zones, was such as the theory before offered would have led us to anticipate. Now there is scarcely any land hitherto examined in Europe, Northern Asia, or North America, which has not been raised from the bosom of the deep, since the origin of the carboniferous rocks, or which, if previously raised, has not subsequently acquired additional altitude. If we were to submerge again all the marine strata, from the transition limestone to the most recent shelly beds, the summits of some primary mountains alone would remain above the waters. These facts, it is true, considered singly, are not conclusive as to the universality of the ancient ocean in the northern hemisphere, because the movements of earthquakes occasion the subsidence as well as the upraising of the surface, and by the alternate rising and sinking of particular spaces, at successive periods, a great area may become entirely

* Our ancient coal-formation has not been found in Italy, Spain, Sicily, or any of the more southern countries of Europe. Whether any of the ammonitiferous limestones of the Southern Apennines and Sicily (Taormina for example) can be considered as of contemporaneous origin with our carboniferous series, is not yet determined; but it is conjectured, from the general character of the organic remains of the Apennine limestones, that they belong to some part of our secondary series, from the lias to the chalk inclusive.

covered with marine deposits, although the whole has never been beneath the waters at one time, nay, even though the relative proportion of land and sea may have continued unaltered throughout the whole period.

There is, however, the highest presumption against such an hypothesis, because the land in the northern hemisphere is now in great excess, and this circumstance alone should induce us to suppose that, amid the repeated changes which the surface has undergone, the sea has usually predominated in a much greater degree. But when we study the mineral composition and fossil contents of the older strata, we find evidence of a more positive and unequivocal kind in confirmation of the same opinion.

State of the surface when the transition and mountain limestones, coal-sandstones, and coal originated.—Calcareous rocks, containing the same class of organic remains as our transition and mountain limestones, extend over a great part of the central and northern parts of Europe, are found in the lake district of North America, and even appear to occur in great abundance as far as the border of the Arctic Sea *. The organic remains of these rocks consist principally of marine shells, corals, and the teeth and bones of fish; and their nature, as well as the continuity of the calcareous beds of homogeneous mineral composition, concur to prove that the whole series was formed in a deep and expansive ocean, in the midst of which, however, there were many isles. These isles were composed partly of primary and partly of volcanic rocks, which being exposed to

* It appears from the observations of Dr. Richardson, made during the expedition under the command of Captain Franklin to the north-west coast of America, and from the specimens presented by him to the Geological Society of London, that, between the parallels of 60° and 70° north latitude, there is a great calcareous formation, stretching towards the mouth of the Mackenzie river, in which are included corallines, productæ, terebratulites, &c., having a close affinity in generic character to those of our mountain limestone, of which the group has been considered the equivalent. There is also in the same region a newer series of strata, in which are shales with impressions of ferns, lepidodendrons, and other vegetables, and also ammonites. These, it is supposed, may belong to the age of our oolitic series.—*Proceedings of Geological Society, March*, 1828.

the erosive action of torrents, to the undermining power of the waves beating against the cliffs, and to atmospheric decomposition, supplied materials for pebbles, sand, and shale, which, together with substances introduced by mineral springs and volcanos in frequent eruption, contributed the inorganic parts of the carboniferous strata.

The disposition of the beds in that portion of this group which is of mechanical origin, and which incloses the coal, has been truly described to be such as would result from the waste of small islands placed in rows and forming the highest points of ridges of submarine mountains. The disintegration of such clusters of isles would produce around and between them detached deposits of various dimensions, which, when subsequently raised above the waters, would resemble the strata formed in a chain of lakes. The insular masses of primary rock would preserve their original relative superiority of height, and would often surround the newer strata on several sides, like the boundary heights of lake basins *.

As might have been expected, the zoophytic, and shelly limestones of the same era, (as the mountain limestone,) sometimes alternate with the rocks of mechanical origin, but appear to have been, in ordinary cases, diffused far and wide over the bottom of the sea, remote from any islands, and where no grains of sand were transported by currents. The associated volcanic rocks resemble the products of submarine eruptions, the tuffs being sometimes interstratified with calcareous shelly beds, or with sandstones, just as might be expected if the sand and ejected matter of which they are probably composed had been intermixed with the waters of the sea, and had then subsided like other sediment. The lavas also often extend in spreading sheets, and must have been poured out on a surface rendered horizontal by sedimentary depositions. There is, moreover, a compactness and general absence of porosity in these igneous rocks which distinguishes them from most of

* See some ingenious remarks to this effect, in the work of M. Ad. Brongniart, Consid. Générales sur la Nat. de la Végét. &c. Ann. des Sci. Nat., Nov. 1828.

those which are produced on the sides of Etna or Vesuvius, and other land volcanos.

The modern submarine lavas of Sicily, which alternate with beds of shells specifically identical with those now living in the Mediterranean, have almost all their cavities filled with calcareous and other ingredients, and have been converted into amygdaloids, and this same change we must suppose such parts of the Etnean lava currents as enter the sea to be undergoing at present, because we know the water on the adjoining coast to be copiously charged with carbonate of lime in solution. It is, therefore, one among many reasons for inferring the submarine origin of our ancient trap rocks, that there are scarcely any instances, in which the cellular hollows, left by bubbles of elastic fluid, have not subsequently been filled by calcareous, siliceous, or other mineral ingredients, such as now abound in the hot springs of volcanic countries.

If, on the other hand, we examine the fossil remains in these strata, we find the vegetation of the coal strata declared by botanists to possess the characters of an insular, not a continental flora, and we may suppose the carbonaceous matter to have been derived partly from trees swept from the rocks by torrents into the sea, and partly from such peaty matter as often discolours and blackens the rills flowing through marshy grounds in our temperate climate, where the vegetation is probably less rank, and its decomposition less rapid than in the moist and hot climate of the era under consideration. There is, however, as yet no well authenticated instance of the remains of a saurian animal having been found in a member of the carboniferous series*.

* It is, indeed, stated, that among other fossils collected from the mountain limestone of Northumberland, the Rev. Charles V. Vernon Harcourt has been fortunate enough

Unius sese dominum fecisse lacertæ,

having found a saurian vertebra together with patellæ and echinal spines, and an impression of a fern analogous to those of the coal-measures in the mountain limestone. Annual Report of the Yorkshire Phil. Soc. for 1826, p. 14. But I am informed by Mr. Harcourt himself, that the vertebra was discovered in loose alluvium.

The larger oviparous reptiles usually inhabit rivers of considerable size in warm latitudes, and had crocodiles and other animals of that class been abundant in a fossil state, as in some of the newer secondary formations, we must have inferred the existence of many rivers, which could only have drained large tracts of land. Nor have the bones of any terrestrial mammalia rewarded our investigations. Had any of these, belonging to quadrupeds of large size, occurred, they would have supplied an argument against the resemblance of the ancient northern archipelagos to those of the modern Pacific, since in the latter no great indigenous quadrupeds have been met with.

It is, indeed, a general character of small islands situated at a remote distance from continents, to be altogether destitute of land quadrupeds, except such as appear to have been conveyed to them by man. Kerguelen's land, which is of no inconsiderable size, placed in a latitude corresponding to that of the Scilly islands, may be cited as an example, as may all the groups of fertile islands in the Pacific Ocean between the tropics, where no quadrupeds have been found, except the dog, the hog, and the rat, which have probably been brought to them by the natives, and also bats, which may have made their way along the chain of islands which extend from the shores of New Guinea far into the southern Pacific *. Even the isles of New Zealand, which may be compared to Ireland and Scotland in dimensions, appear to possess no indigenous quadrupeds, except the bat; and this is rendered the more striking, when we recollect that the northern extremity of New Zealand stretches to latitude 34°, where the warmth of the climate must greatly favour the prolific development of organic life. Lastly, no instance has yet been discovered of a pure lacustrine formation of the carboniferous era; although there are some instances of shells, apparently fresh-water, which may have been washed in by small streams, and do not by any means imply a considerable extent of dry land.

All circumstances, therefore, point to one conclusion :—

* Prichard's Phys. Hist. of Man., vol. i., p. 75.

the subaqueous character of the igneous products—the continuity of the calcareous strata over vast spaces—the marine nature of their organic remains—the basin-shaped disposition of the mechanical rocks—the absence of large fluviatile and of land quadrupeds—the non-existence of pure lacustrine strata—the insular character of the flora,—all concur with wonderful harmony to establish the prevalence throughout the northern hemisphere of a great ocean, interspersed with small isles. If we seek for points of analogy to this state of things, we must either turn to the north Pacific, and its numerous submarine or insular volcanos between Kamtschatka and New Guinea; or, in order to obtain a more perfect counterpart to the coralline and shelly limestones, we may explore the archipelagos of the south Pacific, between Australia and South America, where volcanos are not wanting, and where coral reefs, consisting in great part of compact limestone, are spread over an area not inferior, perhaps, to that of our ancient calcareous rocks, though we suppose these to be prolonged from the lakes of North America to central Europe *.

No geologists have ever denied, that when our oldest conchiferous rocks were produced, great continents were wanting in the temperate and arctic zones north of the equator; but they have even gone farther, and have been disposed to speculate on the universality of what they termed the primeval ocean. As well might the New Zealander, who had surveyed and measured the quantity of land between the south pole and the tropic of Capricorn, assume that the same proportion would be found to exist between the tropic of Cancer and the north pole. By this generalization, he would imagine twelve out of thirteen parts of the land of our temperate and arctic zones to be submerged. Such theorists should be reminded, that if the ocean was ever universal, its mean depth must have been inferior, and if so, the probability of deep water within the arctic circle is much lessened, and the likelihood of a preponderance of ice increased, and the heat of the ancient climate rendered

* See vol. ii. ch. 18.

more marvellous. To this objection, however, they will answer, that they do not profess to restrict themselves to existing analogies, and they may suppose the volume of water in the primeval ocean to have been greater. Besides, the high temperature, say they, was caused by heat which emanated from the interior of the new-born planet.

In vain should we suggest to such reasoners, that when the ocean was in excess in high latitudes, the land in all probability predominated within the tropics, where, being exposed to the direct rays of the sun, it may have heated the winds and currents which flowed from lower to higher latitudes. In vain should we contend that a greater expanse of ocean, if general throughout the globe, would imply a comparative evenness of the superficial crust of the earth, and such an hypothesis would oblige us to conclude that the disturbances caused by subterranean movements in ancient times were inferior to those of later date. Will these arguments be met by the assumption that earthquakes were feebler in the earlier ages, or wholly unknown,—as, according to Werner, there were no volcanos? Such a doctrine would be inconsistent with other popular prejudices respecting the extraordinary violence of the operations of nature in the olden time; and it is probable, therefore, that refuge will be taken in the old dogma of Lazzaro Moro, who imagined that the bed of the first ocean was as regular as its surface, and if so, it may be contended that sufficient time did not elapse between the creation of the world and the origin of the carboniferous strata, to allow the derangement necessary to produce great continents and Alpine chains.

Changes in the physical geography of northern latitudes, between the era of the formation of the carboniferous series and the lias.—But it would be idle to controvert, by reference to modern analogies, the conjectures of those who think they can ascend in their retrospect to the origin of our system. Let us therefore consider what changes the crust of the globe suffered after the consolidation of that ancient series of rocks to which we have adverted. Now, there is evidence that, before

our secondary strata were formed, those of older date (from the old red sandstone to the coal inclusive) were fractured and contorted, and often thrown into vertical positions.

We cannot enter here into the geological details by which it is demonstrable, that, at an epoch extremely remote, some parts of the carboniferous series were lifted above the level of the sea, others sunk to greater depths beneath it, and the former, being no longer protected by a covering of water, were partially destroyed by torrents and the waves of the sea, and supplied matter for newer horizontal beds. These were arranged on the truncated edges of the submarine portions of the more ancient series, and the fragments included in the more modern conglomerates still retain their fossil shells and corals, so as to enable us to determine the parent rocks from whence they were derived *. By such remodelling of the surface, the small islands of the first period increased in size, and new land was introduced into northern regions, consisting partly of primary and volcanic rocks, and partly of the newly-raised carboniferous strata.

Among other proofs that earthquakes were then governed by the same laws which now regulate the subterranean forces, we find that they were restrained within limited areas, so that the site of Germany was not agitated, while that of some parts of England was convulsed. The older rocks, therefore, remained in some cases undisturbed at the bottom of the ancient ocean, and in this case the strata of the succeeding epoch were deposited upon them in conformable position.

By reference to groups largely developed on the continent,

* Thus, for example, on the banks of the Avon, in the Bristol coal-field, the dolomitic conglomerate, a rock of an age intermediate between the carboniferous series and the lias, rests on the truncated edges of the coal and mountain limestone, and contains rolled and angular fragments of the latter, in which are seen the characteristic mountain-limestone fossils. For accurate sections illustrating the disturbances which rocks of the carboniferous series underwent before the newer red sandstone was formed, the reader should consult the admirable memoir on the south-western coal district of England, by Dr. Buckland and Mr. Conybeare. Geol. Trans., vol. i., second series.

but which are some of them entirely wanting, and others feebly represented in our own country, we find that the apparent interruption in the chain of events between the formation of our coal and the lias arises merely from local deficiency in the suite of geological monuments*. During the great interval which separated the formation of these groups, new species of animals and plants made their appearance, and in their turn became extinct; volcanos broke out, and were at length exhausted; rocks were destroyed in one region, and others accumulated elsewhere; while, in the mean time, the geographical condition of the northern hemisphere suffered material modifications. Yet the sea still extended over the greater part of the area now occupied by the lands which we inhabit, and was even of considerable depth in many localities where our highest mountain-chains now rise. The vegetation, during a part at least of this new period (from the lias to the chalk inclusive), appears to have approached to that of the larger islands of the equatorial zone †. These islands appear to have been drained by rivers of considerable size, which were inhabited by crocodiles and gigantic oviparous reptiles, both herbivorous and carnivorous, belonging for the most part to extinct genera. Of the contemporary inhabitants of the land we have as yet acquired but scanty information, but we know that there were flying reptiles, insects, and small mammifera, allied to the opossum.

In further confirmation of the opinion that countries of considerable extent now rose above the sea in the temperate zone,

* In many parts of Germany, the newer red sandstone, and other rocks of about the same age, lie in conformable strata on the coal. In some districts, as in the Thuringerwald, among others, there is an immense series of formations intervening between the coal and the lias; one of these groups, called the *muschelkalkstein*, which seems to have no existence in England, is of great thickness and full of organic remains. See Professor Sedgwick's Memoir on the Geological Relations and Internal Structure of the Magnesian Limestone, &c. Geol. Trans., second series, vol. iii. part i. p. 121.

† Ad. Brongniart, Consid. Générales sur la Nat. de la Végét., &c. Ann. des Sci. Nat., Nov. 1828.

we may mention the discovery of a large estuary formation in the south-east of England of higher antiquity than the chalk, containing terrestrial plants and fresh-water testacea, tortoises, and large reptiles,—in a word, such an assemblage as the delta of the Ganges, or a large river in a hot climate might be expected to produce *.

In the present state of our knowledge, we cannot pretend to institute a close comparison between the climate which prevailed during the gradual deposition of our secondary formations and that of the older carboniferous rocks, for the general temperature of the surface must at both epochs have been so dissimilar to that now experienced in the same, or perhaps in any latitudes, that proofs from analogy lose much of their value, and a larger body of facts is required to support theoretical conclusions. If the signs of intense heat diminish, as some suppose, in the newer groups of this great series, there are nevertheless indications in the animal forms of the continued prevalence of a climate which we might consider as tropical in its character.

Increase of land and elevation of mountains between the origin of the newer secondary and oldest tertiary formations.— We may now turn our attention to the phenomena of the tertiary strata, which afford evidence of an abrupt transition from one description of climate to another. If this remarkable break in the regular sequence of physical events is merely apparent, arising from the present imperfect state of our knowledge, it nevertheless serves to set in a clearer point of view the intimate connexion between great changes in the physical geography of the earth, and revolutions in the mean

* We do not mean to compare the extent of the Wealden formation (from the Weald clay to the Purbeck limestone inclusive) to that of the Gangetic delta, for we shall afterwards see that the most modern addition made to the latter is equal in superficial area to North and South Wales. But, judging from the great continuity of some minor subdivisions of the Wealden group in our island, characterized as they are throughout their whole range by certain fresh-water remains, we may safely conclude that a considerable body of fresh water must have been permanently supplied by a large river.

temperature of the air and water. We have already shown that, when the climate was hottest, the northern hemisphere was for the most part occupied by the ocean, and it remains for us to point out, that the refrigeration did not become considerable until a very large portion of that ocean was converted into land, nor even until it was in some parts replaced by high mountain-chains. Nor did the cold reach its maximum until these chains attained their full height, and the lands their full extension.

A glance at the best geological maps now constructed of various countries in the northern hemisphere, whether in North America or Europe, will satisfy the inquirer that the greater part of the present land has been raised from the deep, either between the period of the deposition of the chalk and that of the strata termed tertiary, or at subsequent periods, during which various tertiary groups were formed in succession. For, as the secondary rocks, from the lias to the chalk inclusive, are, with a few unimportant exceptions, marine, it follows that every district now occupied by them has been converted into land since they originated.

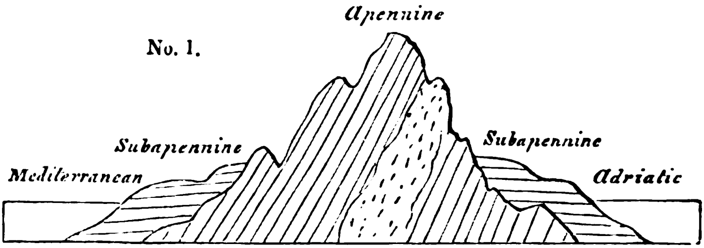
We may prove, by reference to the relative altitudes of the secondary and tertiary groups, and several other circumstances, that a considerable part of the elevation of the older series was accomplished before the newer was formed. The Apennines, for example, as the Italian geologists hinted long before the time of Brocchi, and as that naturalist more clearly demonstrated *, rose several thousand feet above the level of the Mediterranean, before the deposition of the recent Subapennine beds which flank them on either side. What now constitutes the central calcareous chain of the Apennines must for a long time have been a narrow ridgy peninsula, branching off at its northern extremity from the Alps near Savonna. A line of volcanos afterwards burst out in the sea, parallel to the

* The greater number of Italian naturalists, and Brocchi among the rest, attributed the change of level to the lowering of the Mediterranean; rejecting the more correct theory of Moro and his followers, that the land had been upheaved.

axis of the older ridge. These igneous vents were extremely numerous, and the ruins of some of their cones and craters (as those in Tuscany, for example) indicate such a continued series of eruptions, almost all subsequent to the deposition of the Subapennine strata, that we cannot wonder at the vast changes in the relative level of land and sea which were produced.

However minute the effect of each earthquake which preceded or intervened between such countless eruptions, the aggregate result of their elevating or depressing operation may well be expected to display itself in seas of great depth, and hills of considerable altitude. Accordingly, the more recent shelly beds, which often contain rounded pebbles derived from the waste of contiguous parts of the older Apennine rocks, have been raised from one to two thousand feet; but they never attain the loftier eminences of the Apennines, nor penetrate far into the higher and more ancient valleys; for the whole peninsula was evidently subjected to the action of the same subterranean movements, and the older and newer groups of strata changed their level, in relation to the sea, but not to each other.

No. 1.



Transverse Section of the Italian Peninsula.

In the above diagram, exhibiting a transverse section of the Italian peninsula, the superior elevation of the more ancient group, and its uncomformable stratification in relation to the more recent beds, is expressed. The latter, however, are often much more disturbed at the point of contact than is here represented, and in some cases they have suffered such derangement as to dip towards, instead of from, the more ancient chain.

There is usually, moreover, a valley at the junction of the Apennine and Subapennine strata, owing to the greater degradation which the newer and softer beds have undergone; but this intervening depression is not universal.

These phenomena are exhibited in the Alps on a much grander scale; those mountains being encircled by a great zone of tertiary rocks of different ages, both on their southern flank towards the plains of the Po, and on the side of Switzerland and Austria *, and at their eastern termination towards Styria and Hungary. This tertiary zone marks the position of former seas or gulfs, like the Adriatic, which were many thousand feet deep, and wherein strata accumulated, some single groups of which are not inferior in thickness to the whole of our secondary formations in England. These marine tertiary strata rise from the height of from two to four thousand feet and upwards, and consist of formations of different ages, characterized by different assemblages of organized fossils. The older tertiary groups generally rise to greater heights, and form interior zones nearest to the Alps. We may imagine some future convulsion once more to upraise this stupendous chain, together with the adjoining bed of the sea, so that the greatest mountains of Europe might rival the Andes in elevation, in which case the deltas of the Po, Adige, and Brenta, now encroaching upon the Adriatic, might be uplifted so as to form another exterior belt of considerable height around the south-eastern flank of the Alps. Although we have not yet ascertained the number of different periods at which the Alps gained accessions to their height and width, yet we can affirm, that the last series of movements occurred when the seas were inhabited by *many existing species of animals* †.

* See a Memoir by Professor Sedgwick and Mr. Murchison, on the Tertiary Deposits of the Vale of Gosau, in the Salzburg Alps, Proceedings of Geol. Soc. No. xiii., Nov. 1829.

† Brocchi supposed the Subapennine beds to occur *abundantly* on both sides of the plains of the Po; but in this he was mistaken. The subalpine tertiary deposits are for the most part distinct and older formations. Professors Bonelli and Guidotti informed me that they have recognized the Subapennine shells in one or

There appears to be no sedimentary formations in the Alps so ancient as the rocks of our carboniferous series; while, on the other hand, secondary strata as modern as the green sand of English geologists, and perhaps the chalk, enter into some of the higher and central ridges. Down to the period, therefore, when the rocks, from our lias to the chalk inclusive, were deposited, there was sea where now the principal chain of Europe extends, and that chain attained more than half its present elevation and breadth between the eras when our newer secondary and oldest tertiary rocks originated. The remainder of its growth, if we may so speak, is of much more recent date, some of the latest changes, as we have stated, having been coeval with the existence of many animals belonging to species now contemporary with man. The Pyrenees, also, have acquired the whole of their present altitude, which in Mont Perdu exceeds eleven thousand feet, since the origin of some of the newer members of our secondary series. The granitic axis of that chain does not rise so high as a ridge formed by marine calcareous beds, the organic remains of which show them to be the equivalents of our lower chalk, or a formation of about that age *. The tertiary strata at the base of this great chain are only slightly raised above the sea, and retain a horizontal position, without partaking of any of the disturbances to which the older series has been subjected, so that the great barrier between France and Spain was almost entirely upheaved in the interval between the deposition of the secondary and tertiary strata †. The Jura, also, owe the

two districts only north of the Po. They form in these cases, as might have been anticipated, the outermost belt, as at Azolo, at the foot of the Alps near the plains of Venice, and at Bassano, on the Brenta. In the section given by Mr. Murchison of the strata laid open by the Brenta, between Bassano and the Alps above Campese, it will be seen that the older chain must have partaken of the movement which raised the newest tertiary strata of the age of the Subapennines. Phil. Mag. and Annals, June, 1829.

* This observation, first made by M. Boué, has been since confirmed by M. Dufrénoy.

† See a Memoir by M. Elie de Beaumont, Ann. des Sci. Nat., Nov. 1829, p. 286.

greatest part of their present elevation to subterranean convulsions which happened after the deposition of certain tertiary groups; at which time that portion which had been previously raised above the level of the sea underwent an entire alteration of form *.

In other parts of the continent, as in France and England, where the newer rocks lie in basins surrounded by gently-rising hills, we find evidence that considerable spaces were redeemed from the original ocean and converted into dry land after the chalk was formed, and before the origin of the tertiary deposits. In these cases, the secondary strata were not raised into lofty mountain-chains, like the Alps, Apennines, and Pyrenees, but the proofs are not less clear of their partial conversion into land anterior to the tertiary era. The chalk, for example, must have originated in the sea in the form of sediment from tranquil water; but before the tertiary rocks of the Paris and London basins were deposited, large portions of it had been so raised as to be exposed to the destroying power of the elements. The layers of flint had been washed out by torrents and rivers from their cretaceous matrix, rounded by attrition, and transported to the sea, where oysters attached themselves, and in some localities grew to a full size, until covered by other beds of flint-pebbles or sand. These newer derivative deposits are found abundantly along the borders, and in the inferior strata of our tertiary basins, and they are often interstratified with lignite. We may fairly infer, that the various trees and plants which enter into the composition of this lignite, grew on the surface of the same chalk which was then wasting away, and affording to the torrents a constant supply of flint gravel.

We cannot dwell longer on the distinct periods when the secondary and various tertiary groups were upraised, without anticipating details which belong to other parts of this treatise; but we may observe, that although geologists have neglected to point out the relation of changes in the configuration of the

* M. Elie de Beaumont, Dec. 1829, p. 346.

earth's surface with fluctuations in general temperature, they do not dispute the fact, that the sea covered the regions where a great part of the land in Europe is now placed, until after the period when the newer groups of secondary rocks were formed. There is, therefore, confessedly a marked coincidence in point of time between the greatest alteration in climate and the principal revolution in the physical geography of the northern hemisphere.

It is very probable that the abruptness of the transition from the organic remains of the secondary to those of the tertiary epoch, may not be wholly ascribable to the present deficiency of our information. We shall doubtless hereafter discover many intermediate gradations, (and one of these may be recognized in the calcareous beds of Maëstricht,) by which a passage was effected from one state of things to another; but it is not impossible that the interval between the chalk and tertiary formations constituted an era in the earth's history, when the passage from one class of organic beings to another was, comparatively speaking, rapid. For if the doctrines explained by us in regard to vicissitudes of temperature are sound, it will follow that changes of equal magnitude in the geographical features of the globe, may at different periods produce very unequal effects on climate; and, so far as the existence of certain animals and plants depends on climate, the duration of species may often be shortened or protracted, according to the rate at which the change in temperature proceeded.

Let us suppose that the laws which regulate the subterranean forces are constant and uniform, (which we are entitled to assume, until some convincing proofs can be adduced to the contrary,) we may then infer, that a given amount of alteration in the superficial inequalities of the surface of the planet always requires for its consummation nearly equal periods of time. Let us then imagine the quantity of land between the equator and the tropic in one hemisphere to be to that in the other as thirteen to one, which, as we before stated, repre-

sents the unequal proportion of the extra-tropical lands in the two hemispheres at present. Then let the first geographical change consist in the shifting of this preponderance of land from one side of the line to the other, from the southern hemisphere, for example, to the northern. Now this would not affect the *general* temperature of the earth. But if, at another epoch, we suppose a continuance of the same agency to transfer an equal volume of land from the torrid zone to the temperate and arctic regions of the northern hemisphere, there might be so great a refrigeration of the mean temperature *in all latitudes*, that scarcely any of the pre-existing races of animals would survive, and, unless it pleased the Author of Nature that the planet should be uninhabited, new species would be substituted in the room of the extinct. We ought not, therefore, to infer, that equal periods of time are always attended by an equal amount of change in organic life, since a great fluctuation in the mean temperature of the earth, the most influential cause which can be conceived in exterminating whole races of animals and plants, must, in different epochs, require unequal portions of time for its completion.

Maestricht beds.—The only geological monument yet discovered, which throws light on the period immediately succeeding the deposition of the chalk, is the series of calcareous beds in St. Peter's Mount at Maestricht. The turtles and gigantic reptiles there found, seem to indicate that the hot climate of the secondary era had not then been greatly modified; but as it seems that but a small proportion of the fossil species hitherto discovered are identical with known chalk fossils, there may, perhaps, have been a considerable lapse of ages between the consolidation of our upper chalk, and the completion of the Maestricht group *. During these ages,

* It appears from a Memoir by Dr. Fitton, read before the Geological Society of London, Dec. 1829, that the Maestricht beds extend over a considerable area, preserving the same mineral characters and organic remains. Out of fifty species of shells and zoophytes collected by him, ten only could be identified with the copious list of chalk fossils published by Mr. Mantell, in the Geol. Trans., vol. iii. part 1, second series, p. 201.

part of the gradual rise of the Alps and Pyrenees may have been accomplished; for we know that earthquakes may work mighty changes during what we may call a small portion of one zoological era, since there are hills in Sicily which have gained three thousand feet in height, while the assemblage of testacea and zoophytes inhabiting the Mediterranean has only suffered slight alterations, and a large part of the countries bordering the Mediterranean have been remodelled since about one-third of the existing species were in being.

Theory of Central Heat.—Before we conclude this chapter, we may be expected to offer some remarks on the gradual diminution of the supposed central heat of the globe, a doctrine which appears of late years to have increased in popularity. Baron Fourier, after making a curious series of experiments on the cooling of incandescent bodies, has endeavoured by profound mathematical calculations to prove that the actual distribution of heat in the earth's envelope is precisely that which would have taken place if the globe had been formed in a medium of a very high temperature, and had afterwards been constantly cooled *. He supposes that the matter of our planet, as Leibnitz formerly conjectured, was in an intensely heated state at the era of its creation, and that the incandescent fluid nucleus has been parting ever since with portions of its original heat, thereby contracting its dimensions,—a process which has not yet entirely ceased.

But it is admitted, that there are no positive facts in support of this contraction; on the contrary, La Place has shown, by reference to astronomical observations made in the time of Hipparchus, that in the last two thousand years there has been no sensible contraction of the globe by cooling down, for had this been the case, even to an extremely small amount, the day would have been shortened, whereas its length has certainly not diminished during that period by $\frac{1}{300}$th of a second. The reader will bear in mind, that the question as to the

* See a Memoir on the Temperature of the Terrestrial Globe, and the Planetary Spaces, Ann. de Chimie et Phys., tom. xxvii. p. 136. Oct. 1824.

existence of a central heat is very different from that of the gradual refrigeration of the interior of the earth. Many observations and experiments appear to countenance the idea, that in descending from the surface to those slight depths to which man can penetrate, there is a progressive increase of heat; but if this be established, and if, as some are not afraid to infer, we dwell on a thin crust which covers a central ocean of liquid incandescent lava, we ought still to be very reluctant to concede on slight evidence that the internal heat is, or has been, *variable in quantity*.

In our ignorance of the sources and nature of volcanic fire, it seems more consistent with philosophical caution, to assume that there is no instability in this part of the terrestrial system. We know that different regions have been subject in succession to a series of violent subterranean convulsions, and that fissures have opened from which hot vapours, thermal springs, and, at some points, red hot liquid lavas have issued to the surface. This evolution of heat often continues for ages after the extinction of volcanos and after the cessation of earthquakes, as in Central France, for example, and it seems perfectly natural, that each part of the earth's crust should, as M. Fourier states to be the fact, present the appearance of a heated body slowly cooling down. This may be owing to the former universality of the volcanic foci now shifted; but some effect may perhaps be due to that unequal absorption of the solar rays to which we have alluded, when speaking of the different temperature of the earth, according to the varying distribution of its superficial inequalities.

M. Cordier announces as the result of his experiments and observations on the temperature of the interior of the earth, that the heat increases rapidly with the depth, but the increase does not follow the same law over the whole earth, being twice or three times as much in one country as in another, and these differences not being in constant relation either with the latitudes or longitudes of places. All this is precisely what we should have expected to arise from variations in the intensity

of volcanic heat, and from that change of position, which the principal theatres of volcanic action have undergone at different periods, as the geologist can distinctly prove. But M. Cordier conjectures that there is a connexion between such phenomena and the secular refrigeration and contraction of the internal fluid mass, and that the changes of climate, of which there are geological proofs, favour this hypothesis *.

We cannot help suspecting that if it had appeared that *the same species of animals and plants* had continued to inhabit the seas, lakes, and continents, before and after the great physical mutations which the northern hemisphere has undergone since the secondary strata were formed, the difficulty of explaining the ancient climate of the globe would have appeared far more insurmountable than at present. It would have been so contrary to the elementary truths of meteorology to suppose no refrigeration to have followed from the rising of so many new mountain-chains in northern latitudes, that recourse would probably have been had in that case also to cosmological speculations. It might have been argued with much plausibility, that as the accession of high ridges covered with perpetual snow and glaciers had not occasioned any perceptible increase of cold, so as to affect the state of organic life, there must have been some new source of heat which counterbalanced that refrigerating cause. This, it might have been said, was the increased development of *central fire* issuing from innumerable fissures opened in the crust of the earth, when it was shaken by convulsions which raised the Alps and other colossal chains.

But, without entering into further discussion on the merits of the hypothesis of gradual refrigeration, let us hope that experiments will continue to be made, to ascertain whether there be internal heat in the globe, and what laws may govern its distribution. When its existence has been incontrovertibly established, it will be time to inquire whether it be subject to

* See M. Cordier's Memoir on the Temperature of the Interior of the Earth, read to the Academy of Sciences, 4th June, 1827.—Edin. New Phil. Journ. No. viii. p. 273.

secular variations. Should these also be confirmed, we may begin to indulge speculations respecting the cause, but let us not hastily assume that it has reference to the original formation of the planet, with which it might be as unconnected as with its final dissolution.

In the mean time we know that great changes in the external configuration of the earth's crust have at various times taken place, and we may affirm that they *must* have produced *some effect* on climate. The extent of their influence ought, therefore, to form a primary object of inquiry, more especially as there seems an obvious coincidence between the eras at which the principal accessions of land in high latitudes were made, and the successive periods when the diminution of temperature was most decided.

CHAPTER IX.

Further discussion of the question as to the discordance of the ancient and modern causes of change—Theory of the progressive development of organic life—Evidence in its support wholly inconclusive—Vertebrated animals in the oldest strata—Differences between the organic remains of successive formations—Remarks on the comparatively modern origin of the human race—The popular doctrine of successive development not confirmed by the admission that man is of modern origin—Introduction of man, to what extent a change in the system.

THEORY OF THE PROGRESSIVE DEVELOPMENT OF ORGANIC LIFE.

We have considered, in the preceding chapters, many of the most popular grounds of opposition to the doctrine, that all former changes of the organic and inorganic creation are referrible to one uninterrupted succession of physical events, governed by the laws now in operation.

As the principles of the science must always remain unsettled so long as no fixed opinions are entertained on this fundamental question, we shall proceed to examine other objections which have been urged against the assumption of uniformity in the order of nature. We shall cite the words of a late distinguished writer, who has formally advanced some of the weightiest of these objections. 'It is impossible,' he affirms, 'to defend the proposition, that the present order of things is the ancient and constant order of nature, only modified by existing laws—in those strata which are deepest, and which must, consequently, be supposed to be the earliest deposited, forms even of vegetable life are rare; shells and vegetable remains are found in the next order; the bones of fishes and oviparous reptiles exist in the following class; the remains of birds, with those of the same genera mentioned before, in the next order; those of quadrupeds of extinct species in a still more recent class; and it is only in the loose and slightly-consolidated strata

of gravel and sand, and which are usually called diluvian formations, that the remains of animals such as now people the globe are found, with others belonging to extinct species. But, in none of these formations, whether called secondary, tertiary, or diluvial, have the remains of man, or any of his works, been discovered; and whoever dwells upon this subject must be convinced, that the present order of things, and the comparatively recent existence of man as the master of the globe, is as certain as the destruction of a former and a different order, and the extinction of a number of living forms which have no types in being. In the oldest secondary strata there are no remains of such animals as now belong to the surface; and in the rocks, which may be regarded as more recently deposited, these remains occur but rarely, and with abundance of extinct species;—there seems, as it were, a gradual approach to the present system of things, and a succession of destructions and creations preparatory to the existence of man *.'

In the above passages, the author deduces two important conclusions from geological data: first, that in the successive groups of strata, from the oldest to the most recent, there is a progressive development of organic life, from the simplest to the most complicated forms;—secondly, that man is of comparatively recent origin. It will be easy to show that the first of these propositions, though very generally received, has no foundation in fact. The second, on the contrary, is indisputable, and it is important, therefore, to consider how far its admission is inconsistent with the assumption, that the system of the natural world has been uniform from the beginning, or rather from the era when the oldest rocks hitherto discovered were formed.

We shall first examine the geological proofs appealed to in support of the theory of the successive development of animal and vegetable life, and their progressive advancement to a more perfect state. No geologists, who are in possession of all the data now established respecting fossil remains, will for a

* Sir H. Davy, Consolations in Travel, Dialogue III., 'The Unknown.'

moment contend for the doctrine in all its detail, as laid down by the great chemist to whose opinions we have referred. But naturalists, who are not unacquainted with recent discoveries, continue to defend the ancient doctrine in a somewhat modified form. They say that, in the first period of the world, (by which they mean the earliest of which we have yet procured any memorials,) the vegetation consisted almost entirely of cryptogamic plants, while the animals which co-existed were almost entirely confined to zoophytes, testacea, and a few fish. Plants of a less simple structure succeeded in the next epoch, when oviparous reptiles began also to abound. Lastly, the terrestrial flora became most diversified and most perfect when the highest orders of animals, the mammifera and birds, were called into existence.

Now, in the first place, we may observe, that many naturalists have been guilty of no small inconsistency in endeavouring to connect the phenomena of the earliest vegetation with a nascent condition of organic life, and at the same time to deduce, from the numerical predominance of certain types of form, the greater heat of the ancient climate. The arguments in favour of the latter conclusion are without any force, unless we can assume that the rules followed by the Author of Nature in the creation and distribution of organic beings were the same formerly as now; and that as certain families of animals and plants are now most abundant, or exclusively confined to regions where there is a certain temperature, a certain degree of humidity, a certain intensity of light, and other conditions, so also the same phenomena were exhibited at every former era.

If this postulate be denied, and the prevalence of particular families be declared to depend on a certain order of precedence in the introduction of different classes into the earth, and if it be maintained that the standard of organization was raised successively, we must then ascribe the numerical preponderance in the earlier ages of plants of simpler structure, *not to the heat*, but to those different laws which regulate organic life in newly-created worlds. If, according to the laws of pro-

gressive development, cryptogamic plants always flourish for ages before the dicotyledonous order can be established, then is the small proportion of the latter fully explained; for in this case, whatever may have been the mildness or severity of the climate, they could not make their appearance.

Before we can infer an elevated temperature in high latitudes, from the presence of arborescent Ferns, Lycopodiaceæ, and other allied families, we must be permitted to assume, that at all times, past and future, a heated and moist atmosphere pervading the northern hemisphere has a tendency to produce in the vegetation a predominance of analogous types of form. We grant, indeed, that there may be a connexion between an extraordinary profusion of monocotyledonous plants and a youthful condition of the world, if the dogma of certain cosmogonists be true, that planets, like certain projectiles, are always red hot when they are first cast; but to this arbitrary hypothesis, against which we have already protested, we need not again revert.

Between two and three hundred species of plants are now enumerated as belonging to the carboniferous era, and of these a very few only are dicotyledonous*. But these exceptions are as fatal to the doctrine of successive development as if there were a thousand, although they do not by any means invalidate the conclusion in regard to the heat of the ancient climate, for that depends on the numerical relations of the different classes.

Vertebrated animals in the oldest strata.—The animal remains in the most ancient series of European sedimentary rocks (from the graywacke to the coal inclusive), consist chiefly

* Fragments of dicotyledonous wood, which have evidently belonged to at least two different species of trees, have been obtained from the coal-field of Fife, by Dr. Fleming, of Flisk, and the same gentleman has shown me a large dicotyledonous stem which he procured from the graywacke of Cork. See a memoir by Dr. Fleming on the neighbourhood of Cork. (Trans. of Wern. Soc. Edin.) I am informed also by Dr. Buckland, that he has received from the coal-field of Northumberland another specimen of dicotyledonous wood, which is now in the Oxford Museum.

of corals and testacea. Some estimate may generally be formed of the comparative extent of our information concerning the fossil remains of a particular era, by reference to the number of species of shells obtained from a particular group of strata. Some of the rarest species cannot be discovered, unless the more abundant kinds have been found again and again; and if the variety brought to light be very considerable, it proves not only great diligence of research, but a good state of preservation of the organic contents of that formation. In the older rocks, many causes of destruction have operated, of which the influence has been rendered considerable by the immense lapse of ages during which they have acted. Mechanical pressure, derangement by subterranean movements, the action of chemical affinity, the percolation of acidulous waters and other agencies, have obliterated, in a greater or less degree, all traces of organization in fossil bodies. Sometimes only obscure or unintelligible impressions are left, and the lapidifying process has often effaced not only the characters by which the species, but even those whereby the class might be determined.

The number of organic forms which have disappeared from the oldest strata, may be conjectured from the fact, that their former existence is in many cases merely revealed to us by the unequal weathering of an exposed face of rock, by which certain parts are made to stand out in relief. As the number of species of shells found in the English series, from the graywacke to the coal inclusive, after attentive examination, amounts only to between one and two hundred, we cannot be surprised that so few examples of vertebrated animals have as yet occurred. The remains of fish, however, appear in one of the lowest members of the group. Numerous scales of fish have been found by Dr. Fleming in quarries of the old red sandstone at Clashbinnie in Perthshire, where I have myself collected them. These beds are decidedly older than the coal and mountain limestone of Fifeshire, which entirely destroys the theory of the precedence of the simplest forms of animals.

Scales also of a tortoise nearly allied to trionyx occur abundantly in the bituminous schists of Caithness, and in the same formation in the Orkneys in Scotland. Professor Sedgwick and Mr. Murchison confidently pronounce these schists to be of the age of the old red sandstone; so that we have here an example of a fossil reptile in rocks belonging to the oldest part of the carboniferous series *.

The only negative fact, therefore, remaining in support of the doctrine of the imperfect development of the higher orders of animals in remote ages, is the absence of birds and mammalia. The former are generally wanting in deposits of all ages, even where the highest order of animals occurs in abundance. Land mammifera could not, as we have before suggested, be looked for in strata formed in an ocean interspersed with isles, such as we must suppose to have existed in the northern hemisphere, when the carboniferous rocks were formed.

As all are agreed that the ancient strata in question were subaqueous, and for the most part submarine, from what data, we may ask, do naturalists infer the non-existence or even the rarity of warm-blooded quadrupeds in the earlier ages? Have they dredged the bottom of the ocean throughout an area coextensive with that now occupied by the carboniferous rocks, and have they found that with the number of between one and two hundred species of shells they always obtain the remains of at least one land quadruped? Suppose our mariners were to report that on sounding in the Indian ocean near some coral reefs, and at some distance from the land, they drew up on hooks attached to their line portions of a leopard, elephant, or tapir; should we not be sceptical as to the accuracy of their statements; and if we had no doubt of their veracity, might we not suspect them to be unskilful naturalists? or, if the fact were unquestioned, should we not be disposed to believe that some vessel had been wrecked on the spot?

* See Geol. Trans., second series, vol. iii. part 1, p. 144, and for a representation of the scales of the Trionyx, plate 16 of the same part.

The casualties must be rare indeed whereby land quadrupeds are swept by rivers and torrents into the sea, and still rarer must be the contingency of such a floating body not being devoured by sharks or other predaceous fish, such as were those of which we find the teeth preserved in some of the carboniferous strata*. But if the carcass should escape, and should happen to sink where sediment was in the act of accumulating, and if the numerous causes of subsequent disintegration should not efface all traces of the body included for countless ages in solid rock, is it not contrary to all calculation of chances that we should hit upon the exact spot,—that mere point in the bed of the ancient ocean, where the precious relic was entombed? Can we expect for a moment that when we have only succeeded amidst several thousand fragments of corals and shells, in finding a few bones of *aquatic* or *amphibious* animals, that we should meet with a single skeleton of an inhabitant of the land?

Clarence, in his dream, saw 'in the slimy bottom of the deep,'

> —— a thousand fearful wrecks;
> A thousand men, that fishes gnaw'd upon;
> Wedges of gold, great anchors, heaps of pearl.

Had he also beheld amid 'the dead bones that lay scattered by,' the carcasses of lions, deer, and the other wild tenants of the forest and the plain, the fiction would have been deemed unworthy of the genius of Shakspeare. So daring a disregard of probability, so avowed a violation of analogy, would have been condemned as unpardonable even where the poet was painting those incongruous images which present themselves to a disturbed imagination during the visions of the night. But the cosmogonist is not amenable, even in his waking hours, to these laws of criticism; for he assumes either that the order of nature was formerly different, or that the globe was in a condition to which it can never again be reduced by changes which the existing laws of nature can bring about. This

* I have seen in the collection of Dr. Fleming, the teeth of carnivorous fish from the mountain limestone of Fife, which alternates with the coal.

assumption being once admitted, inexplicable anomalies and violations of analogy, instead of offending his judgment, give greater consistency to his reveries.

Organic remains of the Secondary strata.—The organic contents of the secondary strata in general consist of corals and marine shells. Of the latter, the British strata (from the inferior oolite to the chalk inclusive) have yielded about six hundred species. Vertebrated animals are very abundant, but they are almost entirely confined to fish and reptiles. But some remains of cetacea have also been met with in the oolitic series of England *, and the bones of two species of warm-blooded quadrupeds of extinct genera allied to the Opossum †. The occurrence of one individual of the higher classes of mammalia, whether marine or terrestrial, in these ancient strata, is as fatal to the theory of successive development, as if several hundreds had been discovered.

Of the Tertiary strata.—The tertiary strata, as will appear from what we have already stated, were deposited when the physical geography of the northern hemisphere had been entirely altered. Large inland lakes had become numerous, as in Central France and many other countries. There were gulfs of the sea, into which large rivers emptied themselves, where strata were formed like those of the Paris basin. There were then also littoral formations in progress, such as are indicated by the English *Crag*, and the *Faluns* of the Loire. The state of preservation of the organic remains of this period is very different from that of fossils in the older rocks, the colours

* On the authority of Dr. Buckland. Trans. Geol. Soc. vol. i. part 2, second series, p. 394.

† The mammiferous remains of the Stonesfield slate, near Oxford, consist of three or perhaps four jaws, one of which, now in the Oxford Museum, has been examined by M. Cuvier, and pronounced to belong to a species of Didelphis. Another of these valuable fossils, in the possession of my friend Mr. Broderip, appears to be not only specifically, but generically distinct, from that shown to M. Cuvier. See Observations on the Jaw of a fossil Mammiferous Animal found in the Stonesfield Slate, by W. J. Broderip, Esq., Sec. G.S., F.R.S., F.L.S., &c., Zool. Journ., vol. iii., p. 408, 1827.

of the shells, and even the cartilaginous ligaments uniting the valves being in some cases retained. No less than 1122 species of testacea have been found in the beds of the Paris basin, and an equal number in the more modern formations of the Subapennine hills; and it is a most curious fact in natural history, that the zoologist has already acquired more extensive information concerning the testacea which inhabited the ancient seas of northern latitudes at that era, than of those now living in the same parallels in Europe.

Paris basin.—The strata of the Paris basin are partly of fresh-water origin, and filled with the spoils of the land. They have afforded a great number of skeletons of land quadrupeds, but these relics are confined almost entirely to one small member of the group, and their conservation may be considered as having arisen from some local and accidental combination of circumstances. On the other hand, the scarcity of terrestrial mammalia in submarine sediment is elucidated, in a striking manner, by the extremely small number of such remains hitherto procured from the Subapennine hills. The facilities of investigation in these strata, which undergo rapid degradation by rivers and streamlets, are, perhaps, unexampled in the rest of Europe, and they have been examined by collectors for three hundred years.

But although they have already yielded twelve hundred species of testacea, the authenticated examples of associated remains of terrestrial mammalia are extremely scanty; and several of those which have been cited by earlier writers as belonging to the elephant or rhinoceros, have since been declared, by able anatomists, to be the bones of whales and other cetacea. In about five or ten instances, perhaps, bones of the mastodon, rhinoceros, and some other animals, have been observed in this formation with marine shells attached. These must have been washed into the bed of the ancient sea when the strata were forming, and they serve to attest the contiguity of land inhabited by large herbivora, which renders the rarity of such exceptions more worthy of atten-

tion. On the contrary, the number of skeletons of existing animals in the upper Val d'Arno, which are usually considered to be referrible to the same age as the Subapennine beds, occur in a deposit which was formed entirely in an inland lake, surrounded by lofty mountains.

London clay—Plastic clay.—The inferior member of our oldest tertiary formations in England, usually termed the plastic clay, has hitherto proved as destitute of mammiferous remains, as our ancient coal strata; and this point of resemblance between these deposits is the more worthy of observation, because the lignite, in the one case, and the coal in the other, are exclusively composed of terrestrial plants. From the London clay we have procured three or four hundred species of testacea, but the only bones of vertebrated animals are those of reptiles and fish. On comparing, therefore, the contents of these strata with those of our oolitic series, we find the supposed order of precedence inverted. In the more ancient system of rocks, mammalia, both of the land and sea, have been recognized, whereas in the newer, if negative evidence is to be our criterion, nature has made a retrograde, instead of a progressive, movement, and no animals more exalted in the scale of organization than reptiles are discoverable. In a fresh-water formation, however, resting upon the London clay, in the Isle of Wight, probably referrible to about the same epoch, some mammiferous remains have been found *.

Not a single bone of a quadrumanous animal has ever yet been discovered in a fossil state, and their absence has appeared, to some geologists, to countenance the idea that the type of organization most nearly resembling the human came last in the order of creation, and was scarcely perhaps anterior to that of man. But the evidence on this point is quite inconclusive, for we know nothing, as yet, of the details of the various classes of the animal kingdom which inhabited the land up to the consolidation of the newest of the secondary strata; and

* Buckland and Allan, Jameson's Ed. Phil. Journ. No. 27. p. 190. Pratt, Proceedings of Geol. Soc. No. 18, 1831.

when the newest tertiary formations were in progress, the climate does not appear to have been of such a tropical character as seems necessary for the development of the tribe of apes, monkeys, and allied genera. Besides, it must not be forgotten, that almost all the animals which occur in subaqueous deposits are such as frequent marshes, rivers, or the borders of lakes, as the rhinoceros, tapir, hippopotamus, ox, deer, pig, and others. On the other hand, species which live in trees are extremely rare in a fossil state, and we have no data as yet for determining how great a number of the one kind we ought to find, before we have a right to expect a single individual of the other. If, therefore, we are led to infer, from the presence of crocodiles and turtles in the London clay, and from the cocoanuts and spices found in the Isle of Sheppey, that at the period when our older tertiary strata were formed, the climate was hot enough for the quadrumanous tribe, we nevertheless could not hope to discover any of their skeletons until we had made considerable progress in ascertaining what were the contemporary Pachydermata; and not one of these, as we have already remarked, has been discovered as yet in any of the marine strata of this epoch in England.

Recent origin of man.—It is therefore clear that there is no foundation in geological facts for the popular theory of the successive development of the animal and vegetable world, from the simplest to the most perfect forms; and we shall now proceed to consider another question, whether the recent origin of man lends any support to the same doctrine, or how far the influence of man may be considered as such a deviation from the analogy of the order of things previously established, as to weaken our confidence in the uniformity of the course of nature.

We need not dwell on the proofs of the low antiquity of our species, for it is not controverted by any geologist; indeed, the real difficulty which we experience consists in tracing back the signs of man's existence on the earth to that comparatively modern period when species, now his contemporaries, began to

predominate. If there be a difference of opinion respecting the occurrence in certain deposits of the remains of man and his works, it is always in reference to strata confessedly of the most modern order; and it is never pretended that our race co-existed with assemblages of animals and plants, of which *all the species* are extinct. From the concurrent testimony of history and tradition, we learn that parts of Europe, now the most fertile and most completely subjected to the dominion of man, were, less than three thousand years ago, covered with forests, the abode of wild beasts. The archives of nature are in perfect accordance with historical records; and when we lay open the most superficial covering of peat, we sometimes find therein the canoes of the savage, together with huge antlers of the wild stag, or horns of the wild bull. In caves now open to the day in various parts of Europe, the bones of large beasts of prey occur in abundance; and they indicate that, at periods extremely modern in the history of the globe, the ascendency of man, if he existed at all, had scarcely been felt by the brutes *.

No inhabitant of the land exposes himself to so many dangers on the waters as man, whether in a savage or a civilized state, and there is no animal, therefore, whose skeleton is so liable to become imbedded in lacustrine or submarine deposits; nor can it be said that his remains are more perishable than those of other animals, for in ancient fields of battle, as Cuvier has observed, the bones of men have suffered as little decomposition as those of horses which were buried in the same grave. But even if the more solid parts of our species had disappeared, the impression would have remained engraven on the rocks, as have the traces of the tenderest leaves of plants, and the integuments of many animals. Works of art, moreover, composed of the most indestructible materials, would

* We shall discuss in the next volume, when treating of animal remains in caves, the probable antiquity assignable to certain human bones and works of art found intermixed with remains of extinct animals in the cavern of Bize, and in several localities in the department of Herault, in France.

have outlasted almost all the organic contents of sedimentary rocks; edifices, and even entire cities, have, within the times of history, been buried under volcanic ejections, or submerged beneath the sea, or engulphed by earthquakes; and had these catastrophes been repeated throughout an indefinite lapse of ages, the high antiquity of man would have been inscribed in far more legible characters on the framework of the globe than are the forms of the ancient vegetation which once covered the isles of the northern ocean, or of those gigantic reptiles which at later periods peopled the seas and rivers of the northern hemisphere.

Dr. Prichard has argued that the human race have not always existed on the surface of the earth, because 'the strata of which our continents are composed were once a part of the ocean's bed'—'mankind had a beginning, since we can look back to the period when the surface on which they lived began to exist *.' This proof however is insufficient, for many thousands of human beings now dwell in various quarters of the globe where marine species lived within the times of history, and, on the other hand, the sea now prevails permanently over large districts once inhabited by thousands of human beings. Nor can this interchange of sea and land ever cease while the present causes are in existence. A terrestrial species, therefore, may be older than the continents which it inhabits,—aquatic animals and plants of higher antiquity than the lakes and seas which they people.

It is on other grounds that we feel entitled to infer that man is, comparatively speaking, of modern origin; and, if this be assumed, we may ask whether his introduction can be considered as one step in a progressive system by which, as some suppose, the organic world advanced slowly from a more simple to a more perfect state?

Doctrine of successive development not confirmed by the admission that man is of modern origin.—To this question we may reply, that the superiority of man depends not on those

* Phys. Hist. of Mankind, vol. ii. p. 594.

faculties and attributes which he shares in common with the inferior animals, but on his reason, by which he is distinguished from them. If the organization of man were such as would confer a decided pre-eminence upon him, even if he were deprived of his reasoning powers, and provided only with such instincts as are possessed by the lower animals, he might then be supposed to be a link in a progressive chain, especially if it could be shown that the successive development of the animal creation had always proceeded from the more simple to the more compound, from species most remote from the human type to those most nearly approaching to it. But this is an hypothesis which, as we have seen, is wholly unsupported by geological evidence. On the other hand, we may admit that man is of higher dignity than were any pre-existing beings on the earth, and yet question whether his coming was a step in the gradual advancement of the organic world: for the most highly civilized people may sometimes degenerate in strength and stature, and become inferior in their physical attributes to the stock of rude hunters from which they descended. If then the physical organization of man may remain stationary, or even become deteriorated, while the race makes the greatest progress to higher rank and power in the scale of rational being, the animal creation also may be supposed to have made no progress by the addition to it of the human species, regarded merely as a part of the organic world.

But, if this reasoning appear too metaphysical, let us waive the argument altogether, and grant that the animal nature of man, even considered apart from the intellectual, is of higher dignity than that of any other species; still the introduction at a certain period of our race upon the earth raises no presumption whatever that each former exertion of creative power was characterized by the successive development of *irrational* animals of higher orders. The comparison here instituted is between things so dissimilar, that when we attempt to draw such inferences, we strain analogy beyond all reasonable bounds. We may easily conceive that there was a considerable departure

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from the succession of phenomena previously exhibited in the organic world, when so new and extraordinary a circumstance arose, as the union, for the first time, of moral and intellectual faculties capable of indefinite improvement, with the animal nature. But we have no right to expect that there were any similar deviations from analogy—any corresponding steps in a progressive scheme, at former periods, when no similar circumstances occurred.

Introduction of man to what extent a change in the system.—But another and a far more difficult question may arise out of the admission that man is comparatively of modern origin. Is not the interference of the human species, it may be asked, such a deviation from the antecedent course of physical events, that the knowledge of such a fact tends to destroy all our confidence in the uniformity of the order of nature, both in regard to time past and future? If such an innovation could take place after the earth had been exclusively inhabited for thousands of ages by inferior animals, why should not other changes as extraordinary and unprecedented happen from time to time? If one new cause was permitted to supervene, differing in kind and energy from any before in operation, why may not others have come into action at different epochs? Or what security have we that they may not arise hereafter? If such be the case, how can the experience of one period, even though we are acquainted with all the possible effects of the then existing causes, be a standard to which we can refer all natural phenomena of other periods?

Now these objections would be unanswerable, if adduced against one who was contending for the absolute uniformity throughout all time of the succession of sublunary events—if, for example, he was disposed to indulge in the philosophical reveries of some Egyptian and Greek sects, who represented all the changes both of the moral and material world as repeated at distant intervals, so as to follow each other in their former connexion of place and time. For they compared the course of events on our globe to astronomical cycles, and not

only did they consider all sublunary affairs to be under the influence of the celestial bodies, but they taught that on the earth, as well as in the heavens, the same identical phenomena recurred again and again in a perpetual vicissitude. The same individual men were doomed to be re-born, and to perform the same actions as before; the same arts were to be invented, and the same cities built and destroyed. The Argonautic expedition was destined to sail again with the same heroes, and Achilles with his myrmidons, to renew the combat before the walls of Troy.

> Alter erit tum Tiphys et altera quæ vehat Argo
> Dilectos heroas; erunt etiam altera bella,
> Atque iterum ad Trojam magnus mittetur Achilles *.

The geologist, however, may condemn these tenets as absurd, without running into the opposite extreme, and denying that the order of nature has, from the earliest periods, been uniform in the same sense in which we believe it to be uniform at present. We have no reason to suppose, that when man first became master of a small part of the globe, a greater change took place in its physical condition than is now experienced when districts, never before inhabited, become successively occupied by new settlers. When a powerful European colony lands on the shores of Australia, and introduces at once those arts which it has required many centuries to mature; when it imports a multitude of plants and large animals from the opposite extremity of the earth, and begins rapidly to extirpate many of the indigenous species, a mightier revolution is effected in a brief period, than the first entrance of a savage horde, or their continued occupation of the country for many centuries, can possibly be imagined to have produced. If there be no impropriety in assuming that the system is uniform when disturbances so unprecedented occur in certain localities, we can with much greater confidence apply the same language to those primeval ages when the aggregate number and power of the

* Virgil, Eclog. iv. For an account of these doctrines, see Dugald Stewart's Elements of the Philosophy of the Human Mind, vol. ii. chap. ii. sect. 4, and Prichard's Egypt. Mythol. p. 177.

human race, or the rate of their advancement in civilization, must be supposed to have been far inferior.

If the barren soil around Sidney had at once become fertile upon the landing of our first settlers ; if, like the happy isles whereof the poets have given us such glowing descriptions, those sandy tracts had begun to yield spontaneously an annual supply of grain, we might then, indeed, have fancied alterations still more remarkable in the economy of nature to have attended the first coming of our species into the planet. Or if, when a volcanic island like Ischia was, for the first time, brought under cultivation by the enterprise and industry of a Greek colony, the internal fire had become dormant, and the earthquake had remitted its destructive violence, there would then have been some ground for speculating on the debilitation of the subterranean forces, when the earth was first placed under the dominion of man. But after a long interval of rest, the volcano bursts forth again with renewed energy, annihilates one half of the inhabitants, and compels the remainder to emigrate. Such exiles, like the modern natives of Cumana, Calabria, Sumbawa, and other districts, habitually convulsed by earthquakes, would probably form no very exalted estimate of the sagacity of those geological theorists, who, contrasting the *human* with antecedent epochs, have characterized it as *the period of repose.*

In reasoning on the state of the globe immediately before our species was called into existence, we may assume that all the present causes were in operation, with the exception of man, until some geological arguments can be adduced to the contrary. We must be guided by the same rules of induction as when we speculate on the state of America in the interval that elapsed between the period of the introduction of man into Asia, the cradle of our race, and that of the arrival of the first adventurers on the shores of the New World. In that interval, we imagine the state of things to have gone on according to the order now observed in regions unoccupied by man. Even now, the waters of lakes, seas, and the great ocean, which teem with

life, may be said to have no immediate relation to the human race—to be portions of the terrestrial system of which man has never taken, nor ever can take, possession; so that the greater part of the inhabited surface of the planet remains still as insensible to our presence, as before any isle or continent was appointed to be our residence.

The variations in the external configuration of the earth, and the successive changes in the races of animals and plants inhabiting the land and sea, which the geologist beholds when he restores in imagination the scenes presented by certain regions at former periods, are not more full of wonderful or inexplicable phenomena, than are those which a traveller would witness who traversed the globe from pole to pole. Or if there be more to astonish and perplex us in searching the records of the past, it is because one district may, in an indefinite lapse of ages, become the theatre of a greater number of extraordinary events, than the whole face of the globe can exhibit at one time. However great the multiplicity of new appearances, and however unexpected the aspect of things in different parts of the present surface, the observer would never imagine that he was transported from one system of things to another, because there would always be too many points of resemblance, and too much connexion between the characteristic features of each country visited in succession, to permit any doubt to arise as to the continuity and identity of the whole plan.

'In our globe,' says Paley, 'new countries are continually 'discovered, but the old laws of nature are always found in 'them: new plants perhaps, or animals, but always in company with plants and animals which we already know, and 'always possessing many of the same general properties. We 'never get amongst such original, or totally different modes of 'existence as to indicate that we are come into the province of 'a different Creator, or under the direction of a different will. 'In truth, the same order of things attends us wherever we 'go*.' But the geologist is in danger of drawing a contrary

* Natural Theology, chap. xxv.

inference, because he has the power of passing rapidly from the events of one period to those of another—of beholding, at one glance, the effects of causes which may have happened at intervals of time incalculably remote, and during which, nevertheless, no local circumstances may have occurred to mark that there is a great chasm in the chronological series of nature's archives. In the vast interval of time which may really have elapsed between the results of operations thus compared, the physical condition of the earth may, by slow and insensible modifications, have become entirely altered; one or more races of organic beings may have passed away, and yet have left behind, in the particular region under contemplation, no trace of their existence. To a mind unconscious of these intermediate links in the chain of events, the passage from one state of things to another must appear so violent, that the idea of revolutions in the system inevitably suggests itself. The imagination is as much perplexed by such errors, as to time, as it would be if we could annihilate space, and by some power, such as we read of in tales of enchantment, could transfer a person who had laid himself down to sleep in a snowy arctic wilderness, to a valley in a tropical region, where, on awaking, he would find himself surrounded by birds of brilliant plumage, and all the luxuriance of animal and vegetable forms of which nature is there so prodigal. The most reasonable supposition, perhaps, which a philosopher could make, if by the necromancer's art he was placed in such a situation, would be, that he was dreaming; and if a geologist forms theories under a similar delusion, we should not expect him to preserve more consistency in his speculations, than in the train of ideas in an ordinary dream.

But if, instead of inverting the natural order of inquiry, we cautiously proceed in our investigations, from the known to the unknown, and begin by studying the most modern periods of the earth's history, attempting afterwards to decipher the monuments of more ancient changes, we can never so far lose sight of analogy, as to suspect that we have arrived at a new

system, governed by different physical laws. In more recent formations, consisting often of strata of great thickness, the shells of the present seas and lakes, and the remains of animals and plants now living on the land, are imbedded in great numbers. In those of more ancient date, many of the same species are found associated with others now extinct. These unknown kinds again are observed in strata of still higher antiquity, connected with a great number of others which have also no living representatives, till at length we arrive at periods of which the monuments contain exclusively the remains of species with many genera foreign to the present creation.

But even in the oldest rocks which contain organic remains, some genera of marine animals are recognized, of which species still exist in our seas, and these are repeated at different intervals in all the intermediate groups of strata, attesting that, amidst the great variety of revolutions of which the earth's surface has been the theatre, there has never been a departure from the conditions necessary for the existence of certain unaltered types of organization. The uniformity of animal instinct, observes Mr. Stewart *, pre-supposes a corresponding regularity in the physical laws of the universe, 'insomuch that if the established order of the material world were to be essentially disturbed, (the instincts of the brutes remaining the same,) all their various tribes would inevitably perish.'

Now, any naturalist will be convinced, on slight reflection, of the justice of this remark. He will also admit that the same species have always retained the same instincts, and, therefore, that all the strata wherein any of *their* remains occur, must have been formed when the phenomena of inanimate matter were the same as they are in the actual condition of the earth. The same conclusion must also be extended to the extinct animals with which the remains of these living species are associated; and by these means we are enabled to establish the permanence of the existing physical laws, throughout the whole period when the tertiary deposits were formed. We have

* Phil. of the Human Mind, vol. ii. p. 230.

already stated that, during that vast period, a large proportion of all the lands in the northern hemisphere were raised above the level of the sea.

The modifications in the system of which man is the instrument, do not, in all probability, constitute so great a deviation from analogy as we usually imagine; we often, for example, form an exaggerated estimate of the extent of the power displayed by man in extirpating some of the inferior animals, and causing others to multiply; a power which is circumscribed within certain limits, and which, in all likelihood, is by no means exclusively exerted by our species. The growth of human population cannot take place without diminishing the numbers, or causing the entire destruction of many animals. The larger carnivorous species give way before us, but other quadrupeds of smaller size, and innumerable birds, insects, and plants, which are inimical to our interests, increase in spite of us, some attacking our food, others our raiment and persons, and others interfering with our agricultural and horticultural labours. We force the ox and the horse to labour for our advantage, and we deprive the bee of his store; but, on the other hand, we raise the rich harvest with the sweat of our brow, and behold it devoured by myriads of insects, and we are often as incapable of arresting their depredations as of staying the shock of an earthquake, or the course of a stream of burning lava. The changes caused by other species, as they gradually diffuse themselves over the globe, are inferior probably in magnitude, but are yet extremely analogous to those which we occasion. The lion, for example, and the migratory locust, must necessarily, when they first made their way into districts now occupied by them, have committed immense havoc amongst the animals and plants which became their prey. They may have caused many species to diminish, perhaps wholly to disappear; but they must also have enabled some others greatly to augment in number, by removing the natural enemies by which they had been previously kept down.

It is probable from these, and many other considerations,

that as we enlarge our knowledge of the system, we shall become more and more convinced, that the alterations caused by the interference of man deviate far less from the analogy of those effected by other animals than we usually suppose. We are often misled, when we institute such comparisons, by our knowledge of the wide distinction between the instincts of animals and the reasoning power of man; and we are apt hastily to infer, that the effects of a rational and an irrational species, considered merely *as physical agents*, will differ almost as much as the faculties by which their actions are directed. A great philosopher has observed, that we can only command nature by obeying her laws; and this principle is true even in regard to the astonishing changes which are superinduced in the qualities of certain animals and plants by domestication and garden culture. We can only effect such surprising alterations by assisting the development of certain instincts, or by availing ourselves of that mysterious law of their organization, by which individual peculiarities are transmissible from one generation to another.

We are not, however, contending that a real departure from the antecedent course of physical events cannot be traced in the introduction of man. If that latitude of action which enables the brutes to accommodate themselves in some measure to accidental circumstances, could be imagined to have been at any former period so great, that the operations of instinct were as much diversified as are those of human reason, it might perhaps be contended, that the agency of man did not constitute an anomalous deviation from the previously established order of things.

It might then have been said, that the earth's becoming at a particular period the residence of human beings, was an era in the moral, not in the physical world—that our study and contemplation of the earth, and the laws which govern its animate productions, ought no more to be considered in the light of a disturbance or deviation from the system, than the discovery of the satellites of Jupiter should be regarded as a physical

event in the history of those heavenly bodies, however influential they may have become from that time in advancing the progress of sound philosophy among men, and in augmenting human resources by aiding navigation and commerce.

The distinctness, however, of the human, from all other species considered merely as an efficient cause in the physical world, is real, for we stand in a relation to contemporary species of animals and plants, widely different from that which other irrational animals can ever be supposed to have held to each other. We modify their instincts, relative numbers, and geographical distribution, in a manner superior in degree, and in some respects very different in kind from that in which any other species can affect the rest. Besides, the progressive movement of each successive generation of men causes the human species to differ more from itself in power at two distant periods, than any one species of the higher order of animals differs from another. The establishment, therefore, by geological evidence of the first intervention of such a peculiar and unprecedented agency, long after other parts of the animate and inanimate world existed, affords ground for concluding that the experience during thousands of ages of all the events which may happen on this globe would not enable a philosopher to speculate with confidence concerning future contingencies.

If an intelligent being, therefore, after observing the order of events for an indefinite series of ages, had witnessed at last so wonderful an innovation as this, to what extent would his belief in the regularity of the system be weakened?—would he cease to assume that there was permanency in the laws of nature?—would he no longer be guided in his speculations by the strictest rules of induction? To this question we may reply, that had he previously presumed to dogmatize respecting the absolute uniformity of the order of nature, he would undoubtedly be checked by witnessing this new and unexpected event, and would form a more just estimate of the limited range of his own knowledge, and the unbounded extent

of the scheme of the universe. But he would soon perceive that no one of the fixed and constant laws of the animate or inanimate world was subverted by human agency, and that the modifications produced were on the occurrence of new and extraordinary circumstances, and those not of a *physical*, but a *moral* nature. The deviation permitted, would also appear to be as slight as was consistent with the accomplishment of the new *moral* ends proposed, and to be in a great degree temporary in its nature, so that whenever the power of the new agent was withheld, even for a brief period, a relapse would take place to the ancient state of things; the domesticated animal, for example, recovering in a few generations its wild instinct, and the garden-flower and fruit-tree reverting to the likeness of the parent stock.

Now, if it would be reasonable to draw such inferences with respect to the future, we cannot but apply the same rules of induction to the past. It will scarcely be disputed that we have no right to anticipate any modifications in the results of existing causes in time to come, which are not conformable to analogy, unless they be produced by the progressive development of human power, or perhaps from some other new relations between the moral and material worlds. In the same manner we must concede, that when we speculate on the vicissitudes of the animate and inanimate creation in former ages, we have no ground for expecting any anomalous results, unless where man has interfered, or unless clear indications appear of some other *moral* source of temporary derangement. When we are unable to explain the monuments of past changes, it is always more probable that the difficulty arises from our ignorance of all the existing agents, or all their possible effects in an indefinite lapse of time, than that some cause was formerly in operation which has ceased to act; and if in any part of the globe the energy of a cause appears to have decreased, it is always probable, that the diminution of intensity in its action is merely local, and that its force is unimpaired, when the whole globe is considered. But should we ever establish

by unequivocal proofs, that certain agents have, at particular periods of past time, been more potent instruments of change over the entire surface of the earth than they now are, it will be more consistent with philosophical caution to presume, that after an interval of quiescence they will recover their pristine vigour, than to regard them as worn out.

The geologist who yields implicit assent to the truth of these principles, will deem it incumbent on him to examine with minute attention all the changes now in progress on the earth, and will regard every fact collected respecting the causes in diurnal action, as affording him a key to the interpretation of some mystery in the archives of remote ages. Our estimate, indeed, of the value of all geological evidence, and the interest derived from the investigation of the earth's history, must depend entirely on the degree of confidence which we feel in regard to the permanency of the laws of nature. Their immutable constancy alone can enable us to reason from analogy, by the strict rules of induction, respecting the events of former ages, or, by a comparison of the state of things at two distinct geological epochs, to arrive at the knowledge of general principles in the economy of our terrestrial system.

The uniformity of the plan being once assumed, events which have occurred at the most distant periods in the animate and inanimate world will be acknowledged to throw light on each other, and the deficiency of our information respecting some of the most obscure parts of the present creation will be removed. For as by studying the external configuration of the existing land and its inhabitants, we may restore in imagination the appearance of the ancient continents which have passed away, so may we obtain from the deposits of ancient seas and lakes an insight into the nature of the subaqueous processes now in operation, and of many forms of organic life, which though now existing, are veiled from our sight. Rocks, also produced by subterranean fire in former ages at great depths in the bowels of the earth, present us, when upraised by gradual movements, and exposed to the light of heaven,

with an image of those changes which the deep-seated volcano may now occasion in the nether regions. Thus, although we are mere sojourners on the surface of the planet, chained to a mere point in space, enduring but for a moment of time, the human mind is not only enabled to number worlds beyond the unassisted ken of mortal eye, but to trace the events of indefinite ages before the creation of our race, and is not even withheld from penetrating into the dark secrets of the ocean, or the interior of the solid globe; free, like the spirit which the poet described as animating the universe,

> ——— ire per omnes
> Terrasque tractusque maris, cœlumque profundum.

CHAPTER X.

Division of the subject into changes of the organic and inorganic world—Inorganic causes of change divided into the aqueous and igneous—Aqueous causes—Destroying and transporting power of running water—Sinuosities of rivers—Two streams when united do not occupy a bed of double surface—Heavy matter removed by torrents and floods—Recent inundations in Scotland—Effects of ice in removing stones—Erosion of chasms through hard rocks—Excavations in the lavas of Etna by Sicilian rivers—Gorge of the Simeto—Gradual recession of the cataracts of Niagara—Speculations as to the time required for their reaching Lake Erie.

CHANGES OF THE INORGANIC WORLD—AQUEOUS CAUSES.

Division of the subject.—We defined geology to be the science which investigates the former changes that have taken place in the organic, as well as in the inorganic kingdoms of nature; and we now proceed to inquire what changes are now in progress in both these departments. Vicissitudes in the inorganic world are most apparent; and as on them all fluctuations in the animate creation must in a great measure depend, they may claim our first consideration. We may divide the great agents of change in the inorganic world into two principal classes, the aqueous and the igneous. To the former belong Rivers, Torrents, Springs, Currents, and Tides; to the latter, Volcanos and Earthquakes. Both these classes are instruments of decay as well as of reproduction; but they may be also regarded as antagonist forces. The *aqueous* agents are incessantly labouring to reduce the inequalities of the earth's surface to a level, while the *igneous*, on the other hand, are equally active in restoring the unevenness of the external crust, partly by heaping up new matter in certain localities, and partly by depressing one portion, and forcing out another of the earth's envelope.

It is difficult, in a scientific arrangement, to give an accu-

rate view of the combined effects of so many forces in simultaneous operation; because, when we consider them separately, we cannot easily estimate either the extent of their efficacy, or the kind of results which they produce. We are in danger, therefore, when we attempt to examine the influence exerted singly by each, of overlooking the modifications which they produce on one another; and these are so complicated, that sometimes the igneous and aqueous forces co-operate to produce a joint effect, to which neither of them unaided by the other could give rise,—as when repeated earthquakes unite with running water to widen a valley. Sometimes the organic combine with the inorganic causes; as when a reef, composed of shells and corals, protects one line of coast from the destroying power of tides or currents, and turns them against some other point; or when drift timber, floated into a lake, fills a hollow to which the stream would not have had sufficient velocity to convey earthy sediment.

It is necessary, however, to divide our observations on these various causes, and to classify them systematically, endeavouring as much as possible to keep in view that the effects in nature are mixed, and not simple, as they may appear in an artificial arrangement.

In treating, first, of the aqueous causes, we may consider them under two divisions: first, those which are connected with the circulation of water from the land to the sea, under which are included all the phenomena of rivers and springs; secondly, those which arise from the movements of water in lakes, seas, and the ocean, wherein are comprised the phenomena of tides and currents. In turning our first attention to the former division, we find that the effects of rivers may be subdivided into those of a destroying and those of a renovating nature. In the former are included the erosion of rocks and the transportation of matter to lower levels; in the latter, the formation of sand-bars and deltas, the shallowing of seas, &c.

Action of running water.—We shall begin, then, by describing the destroying and transporting power of running water, as

exhibited by torrents and rivers. It is well known that the lands elevated above the sea attract in proportion to their volume and density a larger quantity of that aqueous vapour which the heated atmosphere continually absorbs from the surface of lakes and seas. By these means, the higher regions become perpetual reservoirs of water, which descend and irrigate the lower valleys and plains. In consequence of this provision, almost all the water is first carried to the highest regions, and is then made to descend by steep declivities towards the sea; so that it acquires superior velocity, and removes a greater quantity of soil than it would do if the rain had been distributed over the low plains and high mountains equally in proportion to their relative areas. Almost all the water is also made by these means to pass over the greatest distances which each region affords, before it can regain the sea. The rocks in the higher regions are particularly exposed to atmospheric influences, to frost, rain, and vapour, and to great annual alternations of moisture and desiccation—of cold and heat.

Its destroying and transporting power.—Among the most powerful agents of decay may be mentioned the mechanical action of water, which possesses the remarkable property of expanding during congelation. When water has penetrated into crevices and cavities, it rends open, on freezing, the most solid rocks with the force of a lever, and for this reason, although in cold climates the comparative quantity of rain which falls is very inferior, and although it descends more gradually than in tropical regions, yet the severity of frost, and the greater inequalities of temperature, compensate for this diminished power of degradation, and cause it to proceed with equal, if not greater rapidity than in low latitudes. The solvent power of water also is very great, and acts particularly on the calcareous and alkaline elements of stone, especially when it holds carbonic acid in solution, which is abundantly supplied to almost every large river by springs, and is collected by rain from the atmosphere. The oxygen of the atmosphere is also gradually absorbed by all animal and vegetable productions, and by

almost all mineral masses exposed to the open air. It gradually destroys the equilibrium of the elements of rocks, and tends to reduce into powder, and to render fit for soils, even the hardest aggregates belonging to our globe *. And as it is well known that almost everything effected by rapid combustion may also be effected gradually by the slow absorption of oxygen, the surface of the hardest rocks exposed to the air may be said to be slowly burning away.

When earthy matter has once been intermixed with running water, a new mechanical power is obtained by the attrition of sand and pebbles, borne along with violence by a stream. Running water charged with foreign ingredients being thrown against a rock, excavates it by mechanical force, sapping and undermining till the superincumbent portion is at length precipitated into the stream. The obstruction causes a temporary increase of the water, which then sweeps down the barrier. By a repetition of these land-slips, the ravine is widened into a small, narrow valley, in which sinuosities are caused by the deflexion of the stream first to one side and then to the other. The unequal hardness of the materials through which the channel is eroded, tends also to give new directions to the lateral force of excavation. When by these, or by accidental shiftings of the alluvial matter in the channel, and numerous other causes, the current is made to cross its general line of descent, it eats out a curve in the opposite bank, or the side of the hill bounding the valley, from which curve it is turned back again at an equal angle, and recrossing the line of descent, it gradually hollows out another curve lower down, in the opposite bank, till the whole sides of the valley, or river-bed, present a succession of salient and retiring angles.

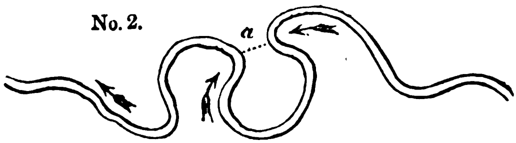
Sinuosities of rivers.—Among the causes of deviation from a straight course by which torrents and rivers tend to widen the valleys through which they flow, may be mentioned the confluence of lateral torrents, swollen irregularly at different seasons in mountainous regions by partial storms, and discharg-

* Sir H. Davy, Consolations in Travel, p. 271.

ing at different times unequal quantities of debris into the main channel.

When the tortuous flexures of a river are extremely great, the aberration from the direct line of descent is often restored by the river cutting through the isthmus which separates two neighbouring curves. Thus, in the annexed diagram, the

No. 2.



extreme sinuosity of the river has caused it to return for a brief space in a contrary direction to its main course, so that a peninsula is formed, and the isthmus (at *a*) is consumed on both sides by currents flowing in opposite directions. In this case an island is soon formed,—on either side of which a portion of the stream usually remains *. These windings occur not only in the channels of rivers flowing through flat alluvial plains, but large valleys also are excavated to a great depth through solid rocks in this serpentine form. In the valley of the Moselle, between Berncastle and Roarn, which is sunk to a depth of from six to eight hundred feet through an elevated platform of transition rocks, the curves are so considerable that the river returns, after a course of seventeen miles in one instance, and nearly as much in two others, to within a distance of a few hundred yards of the spot it passed before †. The valley of the Meuse, near Givet, and many others in different countries, offer similar windings. Mr. Scrope has remarked, that these tortuous flexures are decisively opposed to the hypothesis, that any violent and transient rush of water suddenly swept out such valleys; for great floods would produce straight channels in the direction of the current, not

* See a Paper on the Excavation of Valleys, &c., by G. Poulett Scrope, Esq., Proceedings of Geol. Soc., No. 14, 1830.

† Ibid.

sinuous excavations, wherein rivers flow back again in an opposite direction to their general line of descent.

We must not, however, conclude that the valley of the Meuse was formed simply by river action, for we believe it to have been due in great part to subterranean movements, and the agency of marine currents. Certain it is, that the waters of the sea once filled a great part of this valley, for at St. Mihiel, south of Verdun, about fifteen leagues from Givet, in a tract elevated perhaps one thousand feet above the level of the sea, M. Deshayes discovered three lines of perforations of marine shells, of the genus saxicava, on the boundary cliffs; and, at a corresponding level, the same lines are traceable round two insulated rocks in the middle of the valley. The rock consists of white marble of the Jura limestone formation, and casts of the boring shells still remain in the cavities.

But our present purpose relates to the force of aqueous erosion, and the transportation of materials by running water, considered separately, and not to the question so much controverted respecting the formation of valleys in general. This subject cannot be fully discussed without referring to all the powers to which the inequalities of the earth's surface, and the very existence of land above the level of the sea, are due. Nor even when we have described the influence of all the chemical and mechanical agents which operate at one period in effecting changes in the external form of the land, shall we be enabled to present the reader with a comprehensive theory of the origin of the present valleys. It will be necessary to consider the complicated effects of all these causes at distinct geological epochs, and to inquire how particular regions, after having remained for ages in a state of comparative tranquillity, and under the influence of a certain state of the atmosphere, may be subsequently remodelled by another series of subterranean movements,—how the new direction, volume, and velocity acquired by rivers and torrents may modify the former surface,—what effects an important difference in the mean temperature of the climate, or the greater intensity of heat and cold at different seasons, may

produce,—what pre-existing valleys, under a new configuration of the land, may cease to give passage to large bodies of water, or may become entirely dried up,—how far the relative levels of certain districts in the more modern period may become precisely the reverse of those which prevailed at the more ancient era. When these and other essential elements of the problem are all duly appreciated, the reader will not be surprised to learn, that amongst geologists who have neglected them there has prevailed a great contrariety of opinion on these topics. Some writers of distinguished talent have gone so far as to contend, that the formation of the greater number of existing valleys was simply due to the agency of one cause, and that it was consummated in a brief period of time.

But without discussing the merits of the general question, we may observe that we agree with the author before cited, that the sinuosity of deep valleys is one among many proofs that they have been shaped out progressively, and not by the simultaneous action of one or many causes; and when we consider other agents of change, we shall have opportunities of pointing out a multitude of striking facts in confirmation of the gradual nature of the process to which the inequalities of hill and valley owe their origin.

Transporting power of water.—In regard to the transporting power of water, we are often surprised at the facility wherewith streams of a small size, and which descend a slight declivity, bear along coarse sand and gravel; for we usually estimate the weight of rocks in air, and do not reflect sufficiently on their comparative buoyancy when submerged in a denser fluid. The specific gravity of many rocks is not more than twice that of water, and very rarely more than thrice, so that almost all the fragments propelled by a stream have lost a third, and many of them half of what we usually term their weight.

It has been proved by experiment, in contradiction to the theories of the early writers on hydrostatics, to be a universal law, regulating the motion of running water, that the velocity at the bottom of the stream is everywhere less than in any part

above it, and is greatest at the surface. Also that the superficial particles in the middle of the stream move swifter than those at the sides. This retardation of the lowest and lateral currents is produced by friction, and when the velocity is sufficiently great, the soil composing the sides and bottom gives way. A velocity of three inches per second is ascertained to be sufficient to tear up fine clay,—six inches per second, fine sand,—twelve inches per second, fine gravel,—and three feet per second, stones of the size of an egg *.

When this mechanical power of running water is considered, we are prepared for the transportation of large quantities of gravel, sand, and mud, by the torrents and rivers which descend with great velocity from the mountainous regions. But a question naturally arises, how the more tranquil rivers of the valleys and plains, flowing on comparatively level ground, can remove the prodigious burden which is discharged into them by their numerous tributaries, and by what means they are enabled to convey the whole mass to the sea. If they had not this power, their channels would be annually choked up, and the lower valleys and districts adjoining mountain-chains would be continually strewed over with fragments of rock and sterile sand. But this evil is prevented by a general law regulating the conduct of running water—that two equal streams do not occupy a bed of double surface. In proportion, therefore, as the whole fluid mass increases, the space which it occupies decreases relatively to the volume of water; and hence there is a smaller proportion of the whole retarded by friction against the bottom and sides of the channel. The portion thus unimpeded moves with great velocity, so that the main current is often accelerated in the lower country, notwithstanding that the slope of the channel is lessened.

It not unfrequently happens, as we shall afterwards demonstrate by examples, that two large rivers, after their junction, have only the *surface* which one of them had previously; and even in some cases their united waters are confined in a nar-

* Encycl. Brit.—art. Rivers.

rower bed than each of them filled before. By this beautiful adjustment, the water which drains the interior country is made continually to occupy less room as it approaches the sea; and thus the most valuable part of our continents, the rich deltas, and great alluvial plains, are prevented from being constantly under water *.

Floods in Scotland, 1829.—Many remarkable illustrations of the power of running water in moving stones and heavy materials were afforded by the storm and flood which occurred on the 3rd and 4th of August, 1829, in Aberdeenshire and other counties in Scotland. The elements during this storm assumed all the characters which mark the tropical hurricanes; the wind blowing in sudden gusts and whirlwinds, the lightning and thunder being such as is rarely witnessed in that climate, and heavy rain falling without intermission. The floods extended almost simultaneously, and in equal violence, over that part of the north-east of Scotland which would be cut off by two lines drawn from the head of Lochrannoch, one towards Inverness and another to Stonehaven. The united line of the rivers which were flooded could not be less than from five to six hundred miles in length, and the whole of their courses were marked by the destruction of bridges, roads, crops, and buildings. Sir T. D. Lauder has recorded the destruction of thirty-eight bridges, and the entire obliteration of a great number of farms and hamlets. On the Nairn, a fragment of sandstone rock, fourteen feet long by three feet wide and one foot thick, was carried above two hundred yards down the river. Some new ravines were formed on the sides of mountains where no streams had previously flowed, and ancient river-channels, which had never been filled from time immemorial, gave passage to a copious flood *.

The bridge over the Dee at Ballatu consisted of five arches, having upon the whole a water-way of two hundred and sixty feet. The bed of the river, on which the piers rested, was

* See article Rivers, Encyc. Brit.

† Sir T. D. Lauder's Account of the Great Floods in Morayshire, Aug. 1829.

composed of rolled pieces of granite and gneiss. The bridge was built of granite, and had stood uninjured for twenty years, but the different parts were swept away in succession by the flood, and the whole mass of masonry disappeared in the bed of the river *. 'The river Don,' observes Mr. Farquharson, in his account of the inundations, 'has upon my own premises forced a mass of four or five hundred tons of stones, many of them two or three hundred pounds weight, up an inclined plane, rising six feet in eight or ten yards, and left them in a rectangular heap, about three feet deep, on a flat ground;—the heap ends abruptly at its lower extremity †.'

The power even of a small rivulet, when swoln by rain, in removing heavy bodies, was lately exemplified in the College, a small stream which flows at a moderate declivity from the eastern water-shed of the Cheviot-Hills. Several thousand tons weight of gravel and sand were transported to the plain of the Till, and a bridge then in progress of building was carried away, some of the arch-stones of which, weighing from half to three-quarters of a ton each, were propelled two miles down the rivulet. On the same occasion the current tore away from the abutment of a mill-dam a large block of greenstone-porphyry, weighing nearly two tons, and transported it to the distance of a quarter of a mile. Instances are related as occurring repeatedly, in which from one to three thousand tons of gravel are in like manner removed to great distances in one day ‡.

In the cases above adverted to, the waters of the river and torrent were dammed back by the bridges, which acted as partial barriers, and illustrate the irresistible force of a current when obstructed. Bridges are also liable to be destroyed by the tendency of rivers to shift their course, whereby the pier, or the rock on which the foundation stands, is undermined.

* From the account given by the Rev. James Farquharson, in the Quarterly Journ. of Sci., &c., No. xii., New Series, p. 328. † Ibid., p. 331.

‡ See a paper by Mr. Culley, F.G.S., Proceedings of Geol. Soc. No. xii., 1829.

When we consider how insignificant are the volume and velocity of the rivers and streams in our island, when compared to those of the Alps and other lofty chains, and how, during the various changes which the levels of different districts have undergone, the various contingencies which give rise to floods must in the lapse of ages be multiplied, we may easily conceive that the quantity of loose superficial matter distributed over Europe must be very considerable. That the position also of a great portion of these travelled materials should now appear most irregular, and should often bear no relation to the existing water-drainage of the country, is a necessary consequence, as we shall afterwards see, of the combined operations of running water and subterranean movements.

Effects of ice in removing stones.—In mountainous regions and high northern latitudes, the moving of heavy stones by water is greatly assisted by the ice which adheres to them, and which, forming together with the rock a mass of less specific gravity *, is readily borne along. The glaciers also of alpine regions, formed of consolidated snow, bear down upon their surface a prodigious burden of rock and sand mixed with ice. These materials are generally arranged in long ridges, which, sometimes, in the Alps, are thirty or forty feet high, running parallel to the borders of the glacier, like so many lines of intrenchment. These mounds of debris are sometimes three or more deep, and have generally been brought in by lateral glaciers: the whole accumulation is slowly conveyed to the lower valleys, where, on the melting of the glacier, it is swept away by rivers †.

The rapidity with which even the smallest streams hollow out deep channels in soft and destructible soils is remarkably exemplified in volcanic countries, where the sand and half consolidated tuffs oppose but a slight resistance to the torrents which descend the mountain-side. After the heavy rains which followed the eruption of Vesuvius in 1822, the water

* Silliman's Journal, No. xxx. p. 303.

† Saussure, Voyage dans les Alpes, tome i.

flowing from the Atrio del Cavallo, cut in three days a new chasm through strata of tuff and volcanic ejected matter to the depth of twenty-five feet. The old mule-road was seen in 1828, intersected by this new ravine. But such facts are trifling when compared to the great gorges which are excavated in somewhat similar materials in the great plateau of Mexico, where an ancient system of valleys, originally worn out of granite and secondary rocks, has been subsequently filled with strata of tuff, pumice, lava, and trachytic conglomerate, to the thickness of several thousand feet. The rivers and torrents annually swoln by tropical rains, are now actively employed in removing these more recent deposits, and in re-excavating the ancient water-courses *.

Power of running water to excavate hard rocks.—The gradual erosion of deep chasms through some of the hardest rocks, by the constant passage of running water charged with foreign matter, is another phenomenon of which striking examples may be adduced. Some of the clearest illustrations of this excavating power are presented by many valleys in Central France, where the channels of rivers have been barred up by solid currents of lava, through which the streams have re-excavated a passage to the depth of from twenty to seventy feet and upwards, and often of great width. In these cases there are decisive proofs that neither the sea nor any denuding wave, or extraordinary body of water, have passed over the spot since the melted lava was consolidated. Every hypothesis of the intervention of sudden and violent agency is entirely excluded, because the cones of *loose* scoriæ, out of which the lavas flowed, are oftentimes at no great elevation above the rivers, and have remained undisturbed during the whole period which has been sufficient for the hollowing out of such enormous ravines. But we shall reserve a more detailed account of the volcanic district of Central France for another part of this work, and at present confine ourselves to examples

* I am indebted to Captain Vetch for this information, whose researches in Mexico will, it is hoped, be soon communicated to the scientific world.

derived from events which have happened since the time of history.

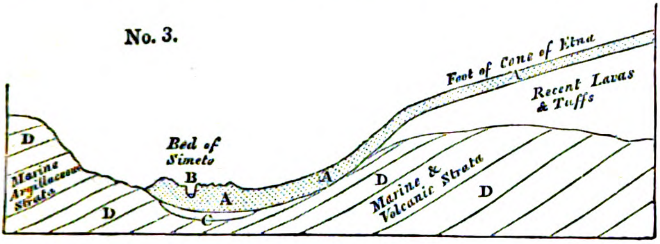
Some lavas of Etna, produced by eruptions of which the date is known, have flowed across two of the principal rivers in Sicily; and in both cases the streams, dispossessed of their ancient beds, have opened for themselves new channels. An eruption from Mount Mojo, an insulated cone at the northern base of Etna, sent forth, in the year 396, B.C., in the reign of Dionysius I., a great lava-stream, which crossed the river Caltabianca in two places. The lowermost point of obstruction is seen on the eastern side of Etna, on the high road from Giardini to Catania, where one pier of the bridge on either bank is based upon a remnant of the solid lava, which has been breached by the river to the depth of fourteen feet. But the Caltabianca, although it has been at work for more than two and twenty centuries, has not worn through the igneous rock so as to lay open the gravel of its ancient bed. The declivity, however, of the alluvial plain is very slight; and as the extent of excavation in a given time depends on the volume and velocity of the stream, and the destructibility of the rock, we must carefully ascertain all these circumstances before we attempt to deduce from such examples a measure of the force of running water in a given period *.

Recent excavation by the Simeto.—The power of running water to hollow out compact rock is exhibited, on a larger scale at the western base of Etna, where a great current of lava (A A, diagram 3), descending from near the summit of the great volcano, has flowed to the distance of five or six miles, and then reached the alluvial plain of the Simeto, the largest of the Sicilian rivers which skirts the base of Etna, and falls into the sea a few miles south of Catania. The lava entered the river about three miles above the town of Adernò,

* I omitted to visit the higher point near the village of Mojo, where the Caltabianca has cut through the lava. Some future traveller would probably derive much instruction from inspecting that spot, which is laid down in Gemmellaro's Quadro Istorico, &c. dell' Etna, 1824.

and not only occupied its channel for some distance, but, cross-

No. 3.



Recent excavation of lava at the foot of Etna by the river Simeto.

ing to the opposite side of the valley, accumulated there in a rocky mass. Gemmellaro gives the year 1603 as the date of the eruption *. The appearance of the current clearly proves that it is one of the most modern of those of Etna, for it has not been covered or crossed by subsequent streams or ejections, and the olives on its surface are all of small size, yet older than the natural wood on the same lava. In the course, therefore, of about two centuries the Simeto has eroded a passage from fifty to several hundred feet wide, and in some parts from forty to fifty feet deep.

The portion of lava cut through is in no part porous or scoriaceous, but consists of a compact homogeneous mass of hard blue rock, somewhat lighter than ordinary basalt, containing crystals of olivine and glassy felspar. The general declivity of this part of the bed of the Simeto is not considerable, but, in consequence of the unequal waste of the lava, two waterfalls occur at Passo Manzanelli, each about six feet in height. Here the chasm (B, diagram No. 3.) is about forty feet deep, and only fifty broad.

The sand and pebbles in the river bed consist chiefly of a brown quartzose sandstone, derived from the upper country; but the matter derived from the volcanic rock itself must have greatly assisted the attrition. This river, like the Caltabianca,

* Quadro Istorico dell' Etna, 1824. Some doubts are entertained as to the exact date of this current by others, but all agree that it is not one of the older streams even of the historical era.

has not yet cut down to the ancient bed of which it was dispossessed, and of which we have indicated the probable position in the annexed diagram (c, No. 3.)

On entering the narrow ravine where the water foams down the two cataracts, we are entirely shut out from all view of the surrounding country; and a geologist who is accustomed to associate the characteristic features of the landscape with the relative age of certain rocks, can scarcely dissuade himself from the belief that he is contemplating a scene in some rocky gorge of a primary district. The external forms of the hard blue lava are as massive as any of the most ancient trap-rocks of Scotland. The solid surface is in some parts smoothed and almost polished by attrition, and covered in others with a white lichen, which imparts to it an air of extreme antiquity, so as greatly to heighten the delusion. But the moment we reascend the cliff, the spell is broken; for we scarcely recede a few paces, before the ravine and river disappear, and we stand on the black and rugged surface of a vast current of lava, which seems unbroken, and which we can trace up nearly to the distant summit of that majestic cone which Pindar called 'the pillar of heaven,' and which still continues to send forth a fleecy wreath of vapour, reminding us that its fires are not extinct, and that it may again give out a rocky stream, wherein other scenes like that now described may present themselves to future observers.

Falls of Niagara.—The falls of Niagara afford a magnificent example of the progressive excavation of a deep valley in solid rock. That river flows from Lake Erie to Lake Ontario, the former lake being three hundred and thirty feet above the latter, and the distance between them being thirty-two miles. On flowing out of the upper lake, the river is almost on a level with its banks; so that if it should rise perpendicularly eight or ten feet, it would lay under water the adjacent flat country of Upper Canada on the West, and of the State of New York on the East*. The river, where it issues, is about three-quarters of

* Captain Hall's Travels in North America, vol. i., p. 179.

a mile in width. Before reaching the falls, it is propelled with great rapidity, being a mile broad, about twenty-five feet deep, and having a descent of fifty feet in half a mile. An island at the very verge of the cataract divides it into two sheets of water; one of these, called the Horse-shoe Fall, is six hundred yards wide, and one hundred and fifty-eight feet perpendicular; the other, called the American Falls, is about two hundred yards in width, and one hundred and sixty-four feet in height. The breadth of the island is about five hundred yards. This great sheet of water is precipitated over a ledge of hard limestone, in horizontal strata, below which is a somewhat greater thickness of soft shale, which decays and crumbles away more rapidly, so that the calcareous rock forms an overhanging mass, projecting forty feet or more above the hollow space below.

The blasts of wind, charged with spray, which rise out of the pool into which this enormous cascade is projected, strike against the shale beds, so that their disintegration is constant; and the superincumbent limestone, being left without a foundation, falls from time to time in rocky masses. When these enormous fragments descend, a shock is felt at some distance, accompanied by a noise like a distant clap of thunder. After the river has passed over the falls, its character, observes Captain Hall, is immediately and completely changed. It then runs furiously along the bottom of a deep wall-sided valley, or huge trench, which has been cut into the horizontal strata by the continued action of the stream during the lapse of ages. The cliffs on both sides are in most places perpendicular, and the ravine is only perceived on approaching the edge of the precipice *.

The waters which expand at the falls, where they are divided by the island, are contracted again, after their union, into a stream not more than one hundred and sixty yards broad. In the narrow channel, immediately below this immense rush of water, a boat can pass across the stream with ease. The pool, it is said, into which the cataract is precipitated, being one hun-

* Captain Hall's Travels in North America, vol. i. pp. 195, 196, 216.

dred and seventy feet deep, the descending water sinks down and forms an under-current, while a superficial eddy carries the upper stratum back *towards* the main fall *. This is not improbable; and we must also suppose, that the confluence of the two streams, which meet at a considerable angle, tends mutually to neutralize their forces. The bed of the river below the falls is strewed over with huge fragments which have been hurled down into the abyss. By the continued destruction of the rocks, the falls have, within the last forty years, receded nearly fifty yards, or, in other words, the ravine has been prolonged to that extent. Through this deep chasm the Niagara flows for about seven miles; and then the table-land, which is almost on a level with Lake Erie, suddenly sinks down at a town called Queenstown, and the river emerges from the ravine into a plain which continues to the shores of Lake Ontario †.

Recession of the Falls.—There seems good foundation for the general opinion, that the falls were once at Queenstown, and that they have gradually retrograded from that place to their present position, about seven miles distant. If the ratio of recession had never exceeded fifty yards in forty years, it must have required nearly ten thousand years for the excavation of the whole ravine; but no probable conjecture can be offered as to the quantity of time consumed in such an operation, because the retrograde movement may have been much more rapid when the whole current was confined within a space not exceeding a fourth or fifth of that which the falls now occupy. Should the erosive action not be accelerated in future, it will require upwards of thirty thousand years for the falls to reach Lake Erie (twenty-five miles distant), to which they seem destined to arrive in the course of time, unless some earthquake changes the relative levels of the district.

* See Mr. Bakewell, jun., on the Falls of Niagara.—Loudon's Magazine, No. xii. March, 1830.

† The Memoir of Mr. Bakewell, jun., above referred to, contains two very illustrative sketches of the physical geography of the country between Lakes Erie and Ontario, including the Falls.

The table-land, extending from Lake Erie, consists uniformly of the same geological formations as are now exposed to view at the falls. The upper stratum is an ancient alluvial sand, varying in thickness from ten to one hundred and forty feet; below which is a bed of hard limestone, about ninety feet in thickness, stretching nearly in a horizontal direction over the whole country, and forming the bed of the river *above* the falls, as do the inferior shales *below*. The lower shale is nearly of the same thickness as the limestone. Should Lake Erie remain in its present state until the period when the ravine recedes to its shores, the sudden escape of that great body of water would cause a tremendous deluge; for the ravine would be much more than sufficient to drain the whole lake, of which the average depth was found, during the late survey, to be only ten or twelve fathoms.

But, in consequence of its shallowness, Lake Erie is fast filling up with sediment, and the annual growth of the deltas of many rivers and torrents which flow into it is remarkable. Long Point, for example, near the influx of Big Creek River, was observed, during the late survey, to advance three miles in as many years. A question therefore arises, whether Lake Erie may not be converted into dry land before the Falls of Niagara recede so far. In speculating on this contingency, we must not omit one important condition of the problem. As the surface of the lake is contracted in size, the loss of water by evaporation will diminish; and unless the supply shall decrease in the same ratio (which seems scarcely probable), Niagara must augment continually in volume, and by this means its retrograde movement may hereafter be much accelerated.

CHAPTER XI.

Action of running water, *continued*—Course of the Po—Desertion of its old channel—Artificial embankments of the Po, Adige, and other Italian rivers—Basin of the Mississippi—Its meanders—Islands—Shifting of its course—Raft of the Atchafalaya—Drift wood—New-formed lakes in Louisiana—Earthquakes in the valley of the Mississippi—Floods caused by land-slips in the White mountains—Bursting of a lake in Switzerland—Devastations caused by the Anio at Tivoli.

ACTION OF RUNNING WATER, *continued.*

Course of the Po.—The Po affords a grand example of the manner in which a great river bears down to the sea the matter poured into it by a multitude of tributaries descending from lofty chains of mountains. The changes gradually effected in the great plain of Northern Italy, since the time of the Roman republic, are very considerable. Extensive lakes and marshes have been gradually filled up, as those near Placentia, Parma, and Cremona, and many have been drained naturally by the deepening of the beds of rivers. Deserted river-courses are not unfrequent, as that of the Serio Morto, which formerly fell into the Adda, in Lombardy; and the Po itself has often deviated from its course. Subsequently to the year 1390, it deserted part of the territory of Cremona, and invaded that of Parma; its old channel being still recognizable, and bearing the name of Po Morto. Bressello is one of the towns of which the site was formerly on the left of the Po, but which is now on the right bank. There is also an old channel of the Po in the territory of Parma, called Po Vecchio, which was abandoned in the twelfth century, when a great number of towns were destroyed. There are records of parish-churches, as those of Vicobellignano, Agojolo, and Martignana, having been pulled down and afterwards rebuilt at a greater distance from the devouring stream. In the fifteenth century the main branch

again resumed its deserted channel, and carried away a great island opposite Casalmaggiore. At the end of the same century it abandoned, a second time, the bed called 'Po Vecchio,' carrying away three streets of Casalmaggiore. The friars in the monastery de' Serviti took the alarm in 1471, demolished their buildings, and reconstructed them at Fontana, whither they had transported the materials. In like manner, the church of S. Rocco was demolished in 1511. In the seventeenth century also the Po shifted its course for a mile in the same district, causing great devastations *.

Artificial embankments of Italian rivers.—To check these and similar aberrations, a general system of embankment has been adopted; and the Po, Adige, and almost all their tributaries, are now confined between high artificial banks. The increased velocity acquired by streams thus closed in, enables them to convey a much larger portion of foreign matter to the sea; and, consequently, the deltas of the Po and Adige have gained far more rapidly on the Adriatic since the practice of embankment became almost universal. But although more sediment is borne to the sea, part of the sand and mud, which in the natural state of things would be spread out by annual inundations over the plain, now subsides in the bottom of the river-channels, and their capacity being thereby diminished, it is necessary, in order to prevent inundations in the following spring, to extract matter from the bed, and to add it to the banks, of the river. Hence it has arisen that these streams now traverse the plain on the top of high mounds, like the waters of aqueducts, and the surface of the Po has become more elevated than the roofs of the houses of the city of Ferrara †. The magnitude of these barriers is a subject of increasing expense and anxiety, it having sometimes of late years been found necessary to give an additional height of nearly one foot to the banks of the Adige and Po in a single season.

* Dell' Antico Corso de' Fiumi Po, Oglio, ed Adda dell' Giovanni Romani. Milan, 1828.

† Prony, see Cuvier, Disc. Prelim., p. 146.

The practice of embankment was adopted on some of the Italian rivers as early as the thirteenth century; and Dante, writing in the beginning of the fourteenth, describes, in the seventh circle of hell, a rivulet of tears separated from a burning sandy desert by embankments 'like those which, between Ghent and Bruges, were raised against the ocean, or those which the Paduans had erected along the Brenta to defend their villas on the melting of the Alpine snows.'

Quale i Fiamminghi tra Guzzante e Bruggia,
Temendo il fiotto che in ver lor s' avventa,
Fanno lo schermo, perchè il mar si fuggia,
E quale i Padovan lungo la Brenta,
Per difender lor ville e lor castelli,
Anzi che Chiarentana il caldo senta—

Inferno, Canto xv.

Basin of the Mississippi.—The hydrographical basin of the Mississippi displays, on the grandest scale, the action of running water on the surface of a vast continent. This magnificent river rises nearly in the forty-ninth parallel of north latitude, and flows to the Gulf of Mexico in the twenty-ninth—a course, including its meanders, of nearly five thousand miles. It passes from a cold arctic climate, traverses the temperate regions, and discharges its waters into the sea in the region of the olive, the fig, and the sugar-cane*. No river affords a more striking illustration of the law before mentioned, that an augmentation of volume does not occasion a proportional increase of surface, nay, is even sometimes attended with a narrowing of the channel. The Mississippi is half a mile wide at its junction with the Missouri †, the latter being also of equal width; yet the united waters have only, from their confluence to the mouth of the Ohio, a medial width of about three-quarters of a mile. The junction of the Ohio seems also to

* Flint's Geography, vol. i. p. 21.

† Flint says (vol. i. p. 140) that, where the Mississippi receives the Missouri, it is a mile and a half wide, but, according to Captain B. Hall, this is a great mistake.—Travels in the United States, vol. iii. p. 328.

produce no increase, but rather a decrease of surface *. The St. Francis, White, Arkansas, and Red rivers, are also absorbed by the main stream with scarcely any apparent increase of its width; and, on arriving near the sea at New Orleans, it is somewhat less than half a mile wide. Its depth there is very variable, the greatest at high water being one hundred and sixty-eight feet. The mean rate at which the whole body of water flows is variously estimated. According to some, it does not exceed one mile an hour †.

The alluvial plain of this great river is bounded on the east and west by great ranges of mountains stretching along their respective oceans. Below the junction of the Ohio, the plain is from thirty to fifty miles broad, and after that point it goes on increasing in width till the expanse is perhaps three times as great! On the borders of this vast alluvial tract are perpendicular cliffs, or 'bluffs,' as they are called, composed of limestone and other rocks. For a great distance the Mississippi washes the eastern 'bluffs;' and below the mouth of the Ohio, never once comes in contact with the western. The waters are thrown to the eastern side, because all the large tributary rivers enter from the west, and have filled that side of the great valley with a sloping mass of clay and sand. For this reason, the eastern bluffs are continually undermined, and the Mississippi is slowly but incessantly progressing eastward ‡.

Curves of the Mississippi.—The river traverses the plain in a meandering course, describing immense and uniform curves. After sweeping round the half of a circle, it is precipitated from the point in a current diagonally across its own channel, to another curve of the same uniformity upon the opposite shore §. These curves are so regular, that the boatmen and Indians calculate distances by them. Opposite to each of

* Flint's Geography, vol. i. p. 142.

† Hall's Travels in North America, vol. iii. p. 330, who cites Darby.

‡ Geograph. Descrip. of the State of Louisiana, by W. Darby, Philadelphia, 1816, p. 102.

§ Flint's Geog., vol. i. p. 152.

them there is always a sand-bar, answering, in the convexity of its form, to the concavity of 'the bend,' as it is called *. The river, by continually wearing these curves deeper, returns, like many other streams before described, on its own tract, so that a vessel in some places, after sailing for twenty-five or thirty miles, is brought round again to within a mile of the place whence it started. When the waters approach so near to each other, it often happens at high floods that they burst through the small tongue of land; and, having insulated a portion, rush through what is called the 'cut off' with great velocity. At one spot called the 'grand cut off,' vessels now pass from one point to another in half a mile to a distance which it formerly required a voyage of twenty miles to reach †.

Waste of its banks.—After the flood season, when the river subsides within its channel, it acts with destructive force upon the alluvial banks, softened and diluted by the recent overflow. Several acres at a time, thickly covered with wood, are precipitated into the stream; and the islands formed by the process before described lose large portions of their outer circumference.

'Some years ago,' observes Captain Hall, 'when the Mississippi was regularly surveyed, all its islands were numbered, from the confluence of the Missouri to the sea; but every season makes such revolutions, not only in the number but in the magnitude and situation of these islands, that this enumeration is now almost obsolete. Sometimes large islands are entirely melted away—at other places they have attached themselves to the main shore, or, which is the more correct statement, the interval has been filled up by myriads of logs cemented together by mud and rubbish ‡.' When the Mississippi and many of its great tributaries overflow their banks, the waters, being no longer borne down by the main current, and becoming impeded amongst the trees and bushes, deposit the sediment of mud and sand with which they are abundantly charged. Islands

* Flint's Geog., vol. i. p. 152. † Ibid., p. 154.

‡ Travels in North America, vol. iii. p. 361.

arrest the progress of floating trees, and they become in this manner reunited to the land; the rafts of trees, together with mud, constituting at length a solid mass. The coarser portion subsides first, and the most copious deposition is found near the banks where the soil is most sandy. Finer particles are found at the farthest distances from the river, where an impalpable mixture is deposited, forming a stiff unctuous black soil. Hence the alluvions of these rivers are highest directly on the banks, and slope back like a natural 'glacis' towards the rocky cliffs bounding the great valley *. The Mississippi, therefore, by the continual shifting of its course, sweeps away, during a great portion of the year, considerable tracts of alluvium which were gradually accumulated by the overflow of former years, and the matter now left during the spring-floods will be at some future time removed.

Raft of the Atchafalaya.—One of the most interesting features in this basin is 'the raft.' The dimensions of this mass of timber were given by Darby in 1816, as ten miles in length, about two hundred and twenty yards wide, and eight feet deep, the whole of which had accumulated, in consequence of some obstruction, during about thirty-eight years, in an arm of the Mississippi called the Atchafalaya, which is supposed to have been at some past time a channel of the Red River, before it intermingled its waters with the main stream. This arm is in a direct line with the direction of the Mississippi, and it catches a large portion of the drift wood annually brought down. The mass of timber in the raft is continually increasing, and the whole rises and falls with the water. Although floating, it is covered with green bushes, like a tract of solid land, and its surface is enlivened in the autumn by a variety of beautiful flowers.

Drift Wood.—Notwithstanding the astonishing number of cubic feet of timber collected here in so short a time, greater deposits have been in progress at the extremity of the delta in the Bay of Mexico. 'Unfortunately for the navigation of the

* Flint's Geography, vol. i. p. 151.

Mississippi,' observes Captain Hall, ' some of the largest trunks, after being cast down from the position on which they grew, get their roots entangled with the bottom of the river, where they remain anchored, as it were, in the mud. The force of the current naturally gives their tops a tendency downwards, and by its flowing past, soon strips them of their leaves and branches. These fixtures, called snags or planters, are extremely dangerous to the steam-vessels proceeding up the stream, in which they lie like a lance in rest, concealed beneath the water, with their sharp ends pointed directly against the bow of vessels coming up. For the most part, these formidable snags remain so still, that they can be detected only by a slight ripple above them, not perceptible to inexperienced eyes. Sometimes, however, they vibrate up and down, alternately showing their heads above the surface and bathing them beneath it *.' So imminent is the danger caused by these obstructions, that almost all the boats on the Mississippi are constructed on a particular plan, to guard against fatal accidents †.

The prodigious quantity of wood annually drifted down by the Mississippi and its tributaries, is a subject of geological interest, not merely as illustrating the manner in which abundance of vegetable matter becomes, in the ordinary course of Nature, imbedded in submarine and estuary deposits, but as attesting the constant destruction of soil and transportation of matter to lower levels by the tendency of rivers to shift their courses. Each of these trees must have required many years, some of them many centuries, to attain their full size; the soil, therefore, whereon they grew, after remaining undisturbed for long

* Travels in North America, vol. iii. p. 362.

† 'The boats are fitted,' says Captain Hall, 'with what is called a snag-chamber;—a partition, formed of stout planks, which is caulked, and made so effectually water-tight, that the foremost end of the vessel is cut off as entirely from the rest of the hold as if it belonged to another boat. If the steam-vessel happen to run against a snag, and that a hole is made in her bow, under the surface, this chamber merely fills with water.' Travels in North America, vol. iii. p. 363.

periods, is ultimately torn up and swept away. Yet notwithstanding this incessant destruction of land and up-rooting of trees, the region which yields this never-failing supply of drift wood is densely clothed with noble forests, and is almost unrivalled in its power of supporting animal and vegetable life.

Innumerable herds of wild deer and bisons feed on the luxurious pastures of the plains. The jaguar, the wolf, and the fox, are amongst the beasts of prey. The waters teem with alligators and tortoises, and their surface is covered with millions of migratory water-fowl, which perform their annual voyage between the Canadian lakes and the shores of the Mexican gulf. The power of man begins to be sensibly felt, and the wilderness to be replaced by towns, orchards, and gardens. The gilded steam-boat, like a moving city, now stems the current with a steady pace—now shoots rapidly down the descending stream through the solitudes of the forests and prairies. Already does the flourishing population of the great valley exceed that of the thirteen United States when first they declared their independence, and after a sanguinary struggle were severed from the parent country *. Such is the state of a continent where rocks and trees are hurried annually, by a thousand torrents, from the mountains to the plains, and where sand and finer matter are swept down by a vast current to the sea, together with the wreck of countless forests and the bones of animals which perish in the inundations. When these materials reach the Gulf, they do not render the waters unfit for aquatic animals; but, on the contrary, the ocean here swarms with life, as it generally does where the influx of a great river furnishes a copious supply of organic and mineral matter. Yet many geologists, when they behold the spoils of the land heaped in successive strata, and blended confusedly with the remains of fishes, or interspersed with broken shells and corals, imagine that they are viewing the signs of a turbulent, instead of a tranquil and settled state of the planet. They read in such phenomena the proof of chaotic disorder, and

* Flint's Geography, vol. i.

reiterated catastrophes, instead of indications of a surface as habitable as the most delicious and fertile districts now tenanted by man. They are not content with disregarding the analogy of the present course of Nature, when they speculate on the revolutions of past times, but they often draw conclusions concerning the former state of things directly the reverse of those to which a fair induction from facts would infallibly lead them.

Formation of lakes in Louisiana.—There is another striking feature in the basin of the Mississippi, illustrative of the changes now in progress, which we must not forget to mention —the formation by natural causes of great lakes, and the drainage of others. These are especially frequent in the basin of the Red River in Louisiana, where the largest of them, called Bistineau, is more than *thirty miles* long, and has a medium depth of from *fifteen* to *twenty* feet. In the deepest parts are seen numerous cypress trees, of all sizes, now dead, and most of them with their tops broken by the wind, yet standing erect under water. This tree resists the action of air and water longer than any other, and, if not submerged throughout the whole year, will retain life for an extraordinary period *. Lake Bistineau, as well as Black Lake, Cado Lake, Spanish Lake, Natchitoches Lake, and many others, have been formed, according to Darby, by the gradual elevation of the bed of Red River, in which the alluvial accumulations have been so great as to raise its channel, and cause its waters, during the flood season, to flow up the mouths of many tributaries, and to convert parts of their courses into lakes. In the autumn, when the level of Red River is again depressed, the waters rush back again, and some lakes become grassy meadows, with streams meandering through them †. Thus,

* Captains Clark and Lewis found a forest of pines standing erect under water in the body of the Columbia River in North America, which they supposed, from the appearance of the trees, to have been only submerged about twenty years.—Vol. ii. p. 241.

† Darby's Louisiana, p. 33.

there is a periodical flux and reflux between Red River and some of these basins; which are merely reservoirs, alternately emptied and filled like our tide estuaries—with this difference, that in the one case the land is submerged for several months continuously, and, in the other, twice in every twenty-four hours. It has happened, in several cases, that a bar has been thrown by Red River across some of the openings of these channels, and then the lakes become, like Bistineau, constant repositories of water. But even in these cases, their level is liable to annual elevation and depression, because the flood when at its height passes over the bar; just as, where sand-hills close the entrance of an estuary on the Norfolk or Suffolk coast, the sea, during some high tide or storm, has often breached the barrier and inundated again the interior.

Earthquakes in basin of Mississippi.—The frequent fluctuations in the direction of river-courses, and the activity exerted by running water in various parts of the basin of the Mississippi, are partly, perhaps, to be ascribed to the co-operation of subterranean movements, which alter from time to time the relative levels of various parts of the surface. So late as the year 1812, the whole valley from the mouth of the Ohio to that of the St. Francis, including a front of three hundred miles, was convulsed to such a degree, as to create new islands in the river, and lakes in the alluvial plain, some of which were *twenty miles in extent.* We shall allude to this event when we treat of earthquakes, but may state here that they happened exactly at the same time as the fatal convulsions at Caraccas; and the district shaken was nearly five degrees of latitude farther removed from the great centre of volcanic disturbance, than the basin of the Red River, to which we before alluded *.

When countries are liable to be so extensively and perma-

* Darby mentions beds of marine shells on the banks of Red River, which seem to indicate that Lower Louisiana is of recent formation: its elevation, perhaps, above the sea, may have been due to the same series of earthquakes which continues to agitate equatorial America.

nently affected by earthquakes, speculations concerning changes in their hydrographical features must not be made without regard to the igneous as well as the aqueous causes of change. It is scarcely necessary to observe, that the inequalities produced even by one shock, might render the study of the alluvial plain of the Mississippi, at some future period, most perplexing to a geologist who should reason on the distribution of transported materials, without being aware that the configuration of the country had varied materially during the time when the excavating or removing power of the river was greatest.

The region convulsed in 1812, of which New Madrid was the centre, exceeded in length the whole basin of the Thames, and the shocks were connected with active volcanos more distant from New Madrid than are the extinct craters of the Eyfel or of Auvergne from London. If, therefore, during the innumerable eruptions which formerly broke forth in succession in the parts of Europe last alluded to, the basin of the principal river of our island was frequently agitated, and the relative levels of its several parts altered (an hypothesis in perfect accordance with modern analogy), the difficulties of some theorists might, perhaps, be removed; and they might no longer feel themselves under the necessity of resorting to catastrophes out of the ordinary course of Nature, when they endeavour to explain the alluvial phenomena of that district.

FLOODS, BURSTING OF LAKES, &c.

The power which running water may exert, in the lapse of ages, in widening and deepening a valley, does not so much depend on the volume and velocity of the stream usually flowing in it, as on the number and magnitude of the obstructions which have, at different periods, opposed its free passage. If a torrent, however small, be effectually dammed up, the size of the valley above the barrier, and its declivity below, will determine the violence of the debacle, and not the dimensions of the torrent. The most universal source of local deluges are land-slips, slides, or avalanches, as they are sometimes

called, when great masses of rock and soil, or sometimes ice and snow, are precipitated into the bed of a river, either by the undermining of a cliff, by the loosening of a sub-stratum by springs, by the shock of an earthquake, or other causes. Volumes might be filled were we to enumerate all the instances which are on record of these terrific catastrophes: we may therefore select a few examples of recent occurrence, the facts of which are well authenticated.

Floods caused by land-slips, 1826.—Two dry seasons in the White Mountains, in New Hampshire, were followed by heavy rains on the 28th August, 1826, when from the steep and lofty declivities which rise abruptly on both sides of the river Saco, innumerable rocks and stones, many of sufficient size to fill a common apartment, were detached, and in their descent swept down before them, in one promiscuous and frightful ruin, forests, shrubs, and the earth which sustained them. No tradition existed of any similar slides at former times, and the growth of the forest on the flanks of the hills clearly showed that for a long interval nothing similar had occurred. One of these moving masses was afterwards found to have slid three miles, with an average breadth of a quarter of a mile. The excavations commenced generally in a trench a few yards in depth and a few rods in width, and descended the mountains, widening and deepening till they became vast chasms. At the base of such hollow ravines was seen a wide and deep mass of ruins, consisting of transported earth, gravel, rocks, and trees. Forests of spruce-fir and hemlock were prostrated with as much ease as if they had been fields of grain; for, where they disputed the ground, the torrent of mud and rock accumulated behind till it gathered sufficient force to burst the temporary barrier.

The valleys of the Amonoosuck and Saco presented, for many miles, an uninterrupted scene of desolation, all the bridges being carried away, as well as those over their tributary streams. In some places, the road was excavated to the depth of from fifteen to twenty feet; in others, it was covered with earth,

rocks, and trees, to as great a height. The water flowed for many weeks after the flood, as densely charged with earth as it could be without being changed into mud, and marks were seen in various localities of its having risen on either side of the valley to more than twenty-five feet above its ordinary level. Many sheep and cattle were swept away, and the Willey family, nine in number, who in alarm had deserted their house, were destroyed on the banks of the Saco; seven of their mangled bodies were afterwards found near the river, buried beneath drift-wood and mountain-ruins *. It is almost superfluous to point out to the reader that the lower alluvial plains are most exposed to such violent floods, and are at the same time best fitted for the sustenance of herbivorous animals. If, therefore, any organic remains are found amidst the superficial heaps of transported matter, resulting from those catastrophes, at whatever periods they may have happened, and whatever may have been the former configuration and relative levels of the country, we may expect the imbedded fossil relics to be principally referrible to this class of mammalia.

But these catastrophes are insignificant, when compared to those which are occasioned by earthquakes, when the boundary hills, for miles in length, are thrown down into the hollow of a valley. We shall have an opportunity of alluding to inundations of this kind when treating of earthquakes, and shall content ourselves at present with selecting an example, of modern date, of a flood caused by the bursting of a lake; the facts having been described, with more than usual accuracy, by scientific observers.

Flood in the Valley of Bagnes, 1818.—The valley of Bagnes is one of the largest of the lateral embranchments of the main valley of the Rhone, above the Lake of Geneva. Its upper portion was, in 1818, converted into a lake by the damming up of a narrow pass, in consequence of the fall of avalanches of snow and ice, precipitated from an elevated glacier into the bed of the river Dranse. In the winter season, during con-

* Silliman's Journal of Science, vol. xv. No. 2, p. 216, Jan. 1829.

tinued frost, scarcely any water flows in the bed of this river to preserve an open channel, so that the ice-barrier remained entire until the melting of the snows in spring, when a lake was formed above, about half a league in length, which finally attained a depth of about two hundred feet in parts, and a width of about seven hundred feet. To prevent or lessen the mischief apprehended from the sudden bursting of the barrier, an artificial gallery, seven hundred feet in length, was cut through the ice, before the waters had risen to a great height. When at length they accumulated and flowed through this tunnel, they dissolved the ice, and thus deepened their channel, until nearly half of the whole contents of the lake were slowly drained off. But, at length, on the approach of the hot season, the central portion of the remaining mass of ice gave way with a tremendous crash, and the residue of the lake was emptied in half an hour. In the course of its descent, the waters encountered several narrow gorges, and at each of these they rose to a great height, and then burst with new violence into the next basin, sweeping along rocks, forests, houses, bridges, and cultivated land. For the greater part of its course the flood resembled a moving mass of rock and mud, rather than of water. Some fragments of primary rock, of enormous magnitude, and which, from their dimensions, might be compared without exaggeration to houses, were torn out of a more ancient alluvion, and borne down for a quarter of a mile. The velocity of the water, in the first part of its course, was thirty-three feet per second, which diminished to six feet before it reached the Lake of Geneva, where it arrived in six hours and a half, the distance being forty-five miles*.

This flood left behind it, on the plains of Martigny, thousands of trees torn up by the roots, together with the ruins of buildings. Some of the houses in that town were filled with mud up to the second story. After expanding in the plain

* See an account of the inundation of the Val de Bagnes, in 1818, in Ed. Phil. Journ., vol. i., p. 187. Drawn up from the Memoir of M. Escher, with a section, &c.

of Martigny, it entered the Rhone, and did no further damage; but some bodies of men, who had been drowned above Martigny, were afterwards found at the distance of about thirty miles, floating on the farther side of the Lake of Geneva, near Vevey.

The waters, on escaping from the lake, intermixed with mud and rock, swept along, for the first four miles, at the rate of above twenty miles an hour; and Mr. Escher, the engineer, calculated that the flood furnished three hundred thousand cubic feet of water every second,—an efflux which is five times greater than that of the Rhine below Basle. Now, if part of the lake had not been gradually drained off, the flood would have been nearly double, approaching in volume to some of the largest rivers in the world. It is evident, therefore, that when we are speculating on the excavating force which running water may have exerted in any particular valley, the most important question is not the volume of the existing stream, nor the present levels of the river-channel, nor the size of the gravel, but the probability of a succession of floods, at some period since the time when some of the land in question may have been first elevated above the bosom of the sea.

For several months after the débâcle of 1818, the Dranse, having no settled channel, shifted its position continually from one side to the other of the valley, carrying away newly-erected bridges, undermining houses, and continuing to be charged with as large a quantity of earthy matter as the fluid could hold in suspension. I visited this valley four months after the flood, and was witness to the sweeping away of a bridge, and the undermining of part of a house. The greater part of the ice-barrier was then standing, presenting a vertical cliff, one hundred and fifty feet high, like the lava-currents of Etna or Auvergne, intersected by a river.

Inundations, precisely similar, are recorded to have occurred at former periods in this district, and from the same cause. In 1595, for example, a lake burst, and the waters, descending with irresistible fury, destroyed the town of Martigny, where

from sixty to eighty persons perished. In a similar flood, fifty years before, one hundred and forty persons were drowned.

Flood at Tivoli, 1826.—We shall conclude with one more example, derived from a land of classic recollections, the ancient Tibur, and which, like all the other inundations to which we have alluded, occurred within the present century. The younger Pliny, it will be remembered, describes a flood on the Anio, which destroyed woods, rocks, and houses, with the most sumptuous villas and works of art *. For four or five centuries consecutively, this headlong stream, as Horace truly called it, has often remained within its bounds, and then, after such long intervals of rest, at different periods inundated its banks again, and widened its channel. The last of these catastrophes happened 15th Nov. 1826, after heavy rains, such as produced the floods before alluded to in Scotland. The waters appear also to have been impeded by an artificial dike, by which they were separated into two parts, a short distance above Tivoli. They broke through this dike, and leaving the left trench dry, precipitated themselves, with their whole weight, on the right side. Here they undermined, in the course of a few hours, a high cliff, and widened the river's channel about fifteen paces. On this height stood the church of St. Lucia, and about thirty-six houses of the town of Tivoli, which were all carried away, presenting, as they sank into the roaring flood, a terrific scene of destruction to the spectators on the opposite bank. As the foundations were gradually removed, each building, some of them edifices of considerable height, was first traversed with numerous rents, which soon widened into large fissures, until at length the roofs fell in with a crash, and then the walls sank into the river, and were hurled down the cataract below †.

The destroying agency of the flood came within two hundred yards of the precipice on which the beautiful temple of Vesta stands; but fortunately this precious relic of antiquity was

* Lib. viii., Epist. 17.

† When at Tivoli, in 1829, I received this account from eye-witnesses of the event.

spared, while the wreck of modern structures was hurled down the abyss. Vesta, it will be remembered, in the heathen mythology, personified the stability of the earth; and when the Samian astronomer, Aristarchus, first taught that the earth revolved on its axis, and round the sun, he was publicly accused of impiety, "for moving the everlasting Vesta from her place." Playfair * observed that when Hutton ascribed instability to the earth's surface, and represented the continents which we inhabit as the theatre of incessant change and movement, his antagonists, who regarded them as unalterable, assailed him, in a similar manner, with accusations founded on religious prejudices. We might appeal to the excavating power of the Anio as corroborative of one of the most controverted parts of the Huttonian theory; and if the days of omens had not gone by, the geologists who now worship Vesta might regard the late catastrophe as portentous. We may, at least, recommend the modern votaries of the goddess to lose no time in making a pilgrimage to her shrine, for the next flood may not respect the temple.

* Illustr. of Hutt. Theory, § 3, p. 147.

CHAPTER XII.

Difference between the transporting power of springs and rivers—Many springs carry matter from below upwards—Mineral ingredients most abundant in springs—Connexion of mineral waters with volcanic phenomena—Calcareous springs—Travertin of the Elsa—Baths of San Vignone and of San Filippo, near Radicofani—Spheroidal structure in travertin, as in English magnesian limestone—Bulicami of Viterbo—Lake of the Solfatara, near Rome—Travertin at Cascade of Tivoli—Ferruginous Springs—Cementing and colouring property of iron—Brine Springs—Carbonated Springs—Disintegration of Auvergne granite—Caverns in limestone—Petroleum Springs—Pitch Lake of Trinidad.

MINERAL SPRINGS.

Difference between the transporting power of springs and rivers.—We have hitherto considered the destroying and transporting power of those atmospheric waters which circulate on the surface of the land; but another portion, which sink deep into the earth, present phenomena essentially different in character. Rivers, as we have seen, remove earthy matter from higher to lower levels, but springs not only effect this purpose, but sometimes, like volcanos, carry matter from below upwards. Almost all springs are impregnated with some foreign ingredients, which render them more agreeable to our taste, and more nutritive than pure rain water; but as their mineral contents are in a state of chemical solution, they rarely, even when in great abundance, affect the clearness of the water, and for this reason we are usually unconscious of the great instrumentality of these agents in the transfer of solid matter from one part of the globe to another. The specific gravity of spring water being greater than that of rain, it augments the carrying power of rivers, enabling them to bear down a greater quantity of matter in mechanical suspension towards the sea. Springs, both cold and thermal, rise up beneath the waters of lakes and seas, as

well as in different parts of the land, and must often greatly modify the mineral character of subaqueous deposits.

Mineral ingredients most abundant in Springs.—The number of metals, earths, acids, and alkalies, held in solution by different springs, comprehends a considerable portion of all known substances, and recent observations have tended continually to augment the list; but those alone which are most abundant, need be regarded as of geological importance. These are lime, iron, magnesia, silica, alumine, soda, and the carbonic and sulphuric acids. Besides these, springs of petroleum, or liquid bitumen, and its various modifications, such as mineral pitch, naphtha, and asphaltum, are largely distributed over the surface of the earth, but usually in close connexion with volcanos.

Connexion of mineral waters with volcanic phenomena.—The relation, indeed, of almost all springs impregnated copiously with mineral matter, to the sources of subterranean heat, seems placed beyond all reasonable doubt by modern research. Mineral waters, as they have been termed, are most abundant in regions of active volcanos, or where earthquakes are most frequent and violent. Their temperature is often very high, and has been known to be permanently heightened or lowered by the shock of an earthquake. The volume of water also given out has been sometimes affected by the same cause. With the exception of silica, the minerals entering most abundantly into *thermal* waters do not seem to differ from those in cold springs. There is, moreover, a striking analogy between the earthy matters evolved in a gaseous state by volcanos, and those wherewith springs in the same region are impregnated; and when we proceed from the site of active to that of extinct volcanos, we find the latter abounding in precisely the same kind of springs. Where thermal and mineral waters occur far from active or extinct volcanos, some great internal derangement in the strata almost invariably marks the site to have been at some period, however remote, the theatre of violent earthquakes.

Origin of Springs.—Springs may, in general, be ascribed to the percolation of rain-water through porous rocks, which, meeting at last with argillaceous strata, is thrown out to the surface. But, in all likelihood, they sometimes descend by fissures, even to the regions of subterranean heat. Michell, in 1760, suggested that those pent-up volcanic vapours which cause earthquakes, penetrate also through rents and cavities, and drive up water impregnated with sulphurous and other matters, whereby springs are charged with their mineral ingredients. Nor is it by any means improbable, that the same power which when intense is able to lift up a column of lava many thousand feet in height, should even in its more languid state be capable of raising to the surface considerable quantities of water from the interior. But as the geographical limits of mineral waters are not confined to volcanic regions, being co-extensive with the whole globe, as far as is hitherto known, we must consider them apart, and in their connexion with rivers rather than volcanos. We might divide the consideration of springs, like that of rivers, into their destroying and reproductive agency; but the former class of effects being chiefly subterranean are beyond the reach of our observation; while their reproductive power consists chiefly in augmenting the quantity of matter deposited by rivers in deltas, or at the bottom of the sea. We shall, therefore, arrange the facts of geo logical interest, respecting mineral springs, under the head of the different ingredients which predominate in their waters.

CALCAREOUS SPRINGS.

Our first attention is naturally directed to springs which are highly charged with calcareous matter; for these produce a variety of phenomena of much interest to the geologist. It is well known that rain-water has the property of dissolving the calcareous rocks over which it flows, and by these means, matter is often supplied for the earthy secretions of testacea, and for the growth of certain plants on which they feed, in the smallest ponds and rivulets. But many springs hold so much carbonic

acid in solution, that they are enabled to dissolve a much larger quantity of calcareous matter than rain-water; and when the acid is dissipated in the atmosphere, the mineral ingredients are slowly thrown down in the form of tufa or travertin.

Auvergne.—Calcareous springs, although most abundant in limestone districts, are by no means confined to them, but flow out indiscriminately from all rock formations. In Central France, a district where the primary rocks are unusually destitute of limestone, springs copiously charged with carbonate of lime rise up through the granite and gneiss. Some of these are thermal, and probably derive their origin from the deep source of volcanic heat, once so active in that region. One of these springs, at the northern base of the hill upon which Clermont is built, issues from volcanic peperino, which rests on granite. It has formed, by its incrustations, an elevated mound of solid travertin, or calc-sinter, as it is sometimes called, two hundred and forty feet in length, and, at its termination, sixteen feet high, and twelve wide. Another incrusting spring, in the same department, situated at Chaluzet, near Pont Gibaud, rises in a gneiss country, at the foot of a regular volcanic cone, at least twenty miles from any calcareous rock. Some masses of tufaceous deposit, produced by this spring, have an oolitic texture.

Valley of the Elsa.—If we pass from the volcanic district of France to that which skirts the Apennines in the Italian peninsula, we meet with innumerable springs, which have precipitated so much calcareous matter, that the whole ground in some parts of Tuscany is coated over with travertin, and sounds hollow beneath the foot.

In other places in the same country, compact rocks are seen descending the slanting sides of hills, very much in the manner of lava-currents, except that they are of a white colour, and terminate abruptly when they reach the course of a river. These consist of the calcareous precipitate of springs, some of them still flowing, while others have disappeared or changed their position. Such masses are frequent on the slope of the

hills which bound the valley of the Elsa, one of the tributaries of the Arno, which flows near Colle, through a valley several hundred feet deep, shaped out of a lacustrine formation, containing fossil shells of existing species. The travertin is unconformable to the lacustrine beds, and its inclination accords with the slope of the sides of the valley *.

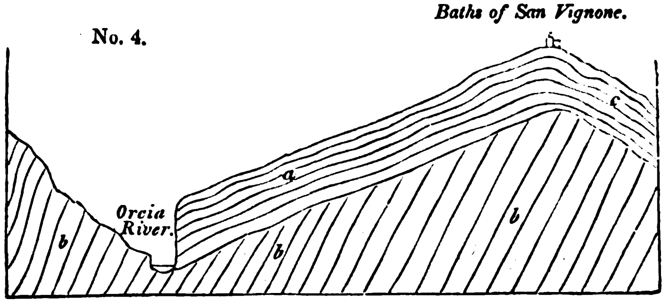
The Sena, and several other small rivulets which feed the Elsa, have the property of lapidifying wood and herbs; and, in the bed of the Elsa itself, aquatic plants, such as charæ, which absorb large quantities of carbonate of lime, are very abundant. Carbonic acid is also seen in the same valley, bubbling up from many springs, where no precipitate of tufa is observable. Targioni, who in his travels has mentioned a great number of mineral waters in Tuscany, found no difference between the deposits of cold and thermal springs. They issue sometimes from the older Apennine limestone, shale, and sandstone, while, in other places, they flow from more modern deposits; but, even in the latter case, their source may probably be in, or below the older series of strata.

Baths of San Vignone.—Those persons who have merely seen the action of petrifying waters in our own country, will not easily form an adequate conception of the scale on which the same process is exhibited in those regions which lie nearer to the modern centres of volcanic disturbance. One of the most striking examples of the rapid precipitation of carbonate of lime from thermal waters occurs in the hill of San Vignone in Tuscany, at a short distance from Radicofani, and only a few hundred yards from the high road between Sienna and Rome. The spring issues from near the summit of a rocky hill, about one hundred feet in height. The top of the hill is flat, and stretches in a gently-inclined plateau to the foot of Mount Amiata, a lofty eminence, which consists in great part of volcanic products. The fundamental rock, from which the spring issues, is a black slate, with serpentine (*b, b, b*, diagram

* One of the finest examples of these which I saw, was at the Molino delle Caldane, near Colle.

4) belonging to the older Apennine formation. The water is

No. 4.



Section of travertin, San Vignone.

hot, has a strong taste, and, when not in very small quantity, is of a bright green colour. So rapid is the deposition near the source, that in the bottom of a conduit-pipe for carrying off the water to the baths, inclined at an angle of 30°, half a foot of solid travertin is formed every year. A more compact rock is produced where the water flows slowly, and the precipitation in winter is said to be more solid and less in quantity by one-fourth than in summer. The rock is generally white: some parts of it are compact, and ring to the hammer; others are cellular, and with such cavities as are seen in the carious part of bone or the siliceous meulière of the Paris basin. A portion of it also below the village consists of long vegetable tubes. Sometimes the travertin assumes precisely the botroidal and mammillary forms, common to similar deposits, in Auvergne, of a much older date, hereafter to be mentioned; and, like them, it often scales off in thin, slightly-undulating layers.

A large mass of travertin (*c*, diagram 4) descends the hill from the point where the spring issues, and reaches to the distance of about half a mile east of San Vignone. The beds take the slope of the hill at about an angle of 6°, and the planes of stratification are perfectly parallel. One stratum, composed of many layers, is of a compact nature and fifteen feet thick; it serves as an excellent building stone, and a mass of fifteen feet in length was, in 1828, cut out for the new bridge

over the Orcia. Another branch of it (*a*, diagram 4) descends to the west, for two hundred and fifty feet in length, of varying thickness, but sometimes two hundred feet deep; it is then cut off by the small river Orcia, precisely as some glaciers in Switzerland descend into a valley till their progress is suddenly arrested by a transverse stream of water.

The abrupt termination of the mass of rock at the river, when its thickness is undiminished, clearly shows that it would proceed much farther if not arrested by the stream, over which it impends slightly. But it cannot encroach upon the channel of the Orcia, being constantly undermined, so that its solid fragments are seen strewed amongst the alluvial gravel. However enormous, therefore, the mass of solid rock may appear which has been given out by this single spring, we may feel assured that it is insignificant in volume, when compared to that which has been carried to the sea since the time when it began to flow. What may have been the length of that period of time, we have no data for conjecturing. In quarrying the travertin, Roman tiles have been sometimes found at the depth of five or six feet.

Baths of San Filippo.—On another hill, not many miles from that last mentioned, and also connected with Mount Amiata, the summit of which is about three miles distant, are the celebrated baths of San Filippo. The subjacent rocks consist of alternations of black slate, limestone, and serpentine, of highly inclined strata, belonging to the Apennine formation; and, as at San Vignone, near the boundary of a tertiary basin of marine origin, consisting chiefly of blue argillaceous marl. There are three warm springs here, containing carbonate and sulphate of lime, and sulphate of magnesia. The water which supplies the bath falls into a pond, where it has been known to deposit a solid mass *thirty feet thick*, in about *twenty years* *. A manufactory of medallions in basso-relievo is carried on at these baths. The water is conducted by canals into several pits, in which it deposits travertin and

* Dr. Grosse, on the Baths of San Filippo. Ed. Phil. Journ. v. 2, p. 292.

crystals of sulphate of lime. After being thus freed from its grosser parts, it is conveyed by a tube to the summit of a small chamber, and made to fall through a space of ten or twelve feet. The current is broken in its descent by numerous crossed sticks, by which the spray is dispersed around upon certain moulds, which are rubbed lightly over with a solution of soap, and a deposition of solid matter like marble is the result, yielding a beautiful cast of the figures formed in the mould *. The geologist may derive from these experiments considerable light, in regard to the high inclination at which some semicrystalline precipitations can be formed; for some of the moulds are disposed almost perpendicularly, yet the deposition is nearly equal in all parts.

A hard stratum of stone about a foot in thickness, is obtained from the waters of San Filippo in four months; and, as the springs are powerful, and almost uniform in the quantity given out, we are at no loss to comprehend the magnitude of the mass which descends the hill, which is a mile and quarter in length and the third of a mile in breadth, in some places attaining a thickness of two hundred and fifty feet at least. To what length it might have reached, it is impossible to conjecture, as it is cut off, like the travertin of San Vignone, by a small stream, where it terminates abruptly. The remainder of the matter held in solution is carried on probably to the sea.

Spheroidal structure in travertin.—But what renders this recent calcareo-magnesian limestone of peculiar interest to the geologist, is the spheroidal forms which it assumes, offering so striking an analogy, on the one hand, to the concentric structure displayed in the calcareous travertin of the cascade of Tivoli, and on the other, to the spheroidal forms of the English magnesian limestone of Sunderland. Between this latter and many of the appearances exhibited at San Filippo, and several other recent deposits of the same kind in Italy, there is every feature of resemblance; the same combination of con-

* Dr. Grosse, on the Baths of San Filippo. Ed. Phil. Journ., v. 2, p. 297.

centric and radiated structure, with small undulations in each concentric ring, occasional interferences of one circle with another, and a small globular structure subordinate to the large spheroidal, with frequent examples of laminæ passing off from the external coating of a spheroid into layers parallel to the general plane of stratification. There are also cellular cavities and vacuities in the rock, constituting what has been termed a honeycombed texture. The lamination of some of the concentric masses of San Filippo is so minute, that sixty may be counted in the thickness of an inch. Yet, notwithstanding these marks of gradual and successive deposition, the symmetry and magnitude of many of the spheroidal forms might convey the idea, that the whole was the result of chemical action, simultaneously operating on a great mass of matter.

Compared to that of English magnesian limestone.—The concretionary forms of our magnesian limestone have been supposed by some to have been superinduced after the component parts of the rock had been brought together in stratiform masses; but a careful comparison of those older rocks with the numerous travertins now in progress of formation in Italy leads the observer to a different conclusion. Such a structure seems to be the result of gradual precipitation, and not of subsequent re-arrangement of the particles *. Each

* The structure of the English magnesian limestone has been described, in an elaborate and profound paper on that formation, by Professor Sedgwick. Geol. Trans., vol. 3, second series, part i., p. 37. Examples of almost all the modifications of concretionary arrangement, together with the brecciated and honeycombed structure to which he alludes, may be found either in the deposits of travertin springs in various parts of Italy, or in the subaqueous travertins of Auvergne and Sicily,—the former of lacustrine, the latter of submarine origin. These will be alluded to in their proper places, and I shall merely observe here, that, after examining these more recent deposits, I visited Sunderland, and recognized a degree of identity in the various and complicated forms there assumed by the magnesian limestone, which satisfied me that the circumstances under which they were formed must have been perfectly analogous to those under which the mineral springs of volcanic countries are now giving birth to calcareous, calcereo-magnesian, and calcereo-siliceous rocks.

minute particle of foreign matter, a reed, or the fragment of a shell, forms a nucleus, around which accessions of new laminæ are formed, until spheroids and elongated cones, from a few inches to several feet in diameter, are produced; for, as the precipitate is arranged by the force of chemical affinity, and not of gravity, the different layers continue of the same thickness, and preserve the original form of the nucleus.

Bulicami of Viterbo.—We must not attempt to describe all the places in Italy where the constant formation of limestone may be seen, as on the Silaro, near Pæstum, on the Velino at Terni, and near the Bulicami, or hot baths in the vicinity of Viterbo. About a mile and a half north of the latter town, in the midst of a sterile plain of volcanic sand and ashes, a monticule is seen, about twenty feet high and five hundred yards in circumference, entirely composed of concretionary travertin. The laminæ are extremely thin, and their minute undulations are so arranged, that the whole mass has at once a concentric and radiated structure. This rock has been largely quarried for lime, and much of it appears to have been removed. It seems to have been formed by a small jet or fountain of calcareous water, which continued to rise through the mound of travertin, which it gradually raised by overflowing from the summit. A spring of hot water still issues in the neighbourhood, which is conveyed to an open tank, used as a bath, the bottom and sides of which, as well as the open conduit which conveys the water, are encrusted with travertin.

Campagna di Roma.—The country around Rome, like many parts of the Tuscan States already referred to, has been at some former period the site of numerous volcanic eruptions; and the springs are still copiously impregnated with lime, carbonic acid, and sulphuretted hydrogen. A hot spring has lately been discovered near Civita Vecchia, by Riccioli, which deposits alternate beds of a yellowish travertin, and a white granular rock, not distinguishable, in hand specimens, either in grain, colour,

or composition, from statuary marble. There is a passage between this and ordinary travertin. The mass accumulated near the spring is in some places about six feet thick *.

Lake of the Solfatara.—In the Campagna, between Rome and Tivoli, is the lake of the Solfatara, called also Lago di Zolfo, (lacus albula,) into which flows continually a stream of tepid water, from a smaller lake situated a few yards above it. The water is a saturated solution of carbonic acid gas, which escapes from it in such quantities in some parts of its surface, that it has the appearance of being actually in ebullition. 'I have found by experiment,' says Sir Humphry Davy, 'that the water taken from the most tranquil part of the lake, even after being agitated and exposed to the air, contained in solution more than its own volume of carbonic acid gas, with a very small quantity of sulphuretted hydrogen. Its high temperature, which is pretty constant at 80° of Fahr., and the quantity of carbonic acid that it contains, render it peculiarly fitted to afford nourishment to vegetable life. The banks of travertin are every where covered with reeds, lichen, confervæ, and various kinds of aquatic vegetables; and at the same time that the process of vegetable life is going on, the crystallizations of the calcareous matter, which is every where deposited in consequence of the escape of carbonic acid, likewise proceed.—There is, I believe, no place in the world where there is a more striking example of the opposition or contrast of the laws of animate and inanimate nature, of the forces of inorganic chemical affinity, and those of the powers of life †.'

The same observer informs us, that he fixed a stick on a mass of travertin covered by the water in May, and in the April following he had some difficulty in breaking, with a

* I did not visit this spring myself, but Signor Riccioli, whose acquaintance with the geology of the environs of Rome is well known, favoured me with an inspection of a suite of specimens collected from the spot. Brocchi, a few years before his death, visited the locality in company with Signor Riccioli, and was much struck with the phenomenon, of which he had intended to publish a description.

† Consolations in Travel, p. 123—125.

sharp-pointed hammer, the mass which adhered to the stick, and which was several inches in thickness. The upper part was a mixture of light tufa and the leaves of confervæ: below this was a darker and more solid travertin, containing black and decomposed masses of confervæ; in the inferior part the travertin was more solid, and of a grey colour, but with cavities probably produced by the decomposition of vegetable matter *.

The stream which flows out of this lake fills a canal about nine feet broad and four deep, and is conspicuous in the landscape by a line of vapour which rises from it. It deposits tufa in this channel, and the Tiber probably receives from it, as well as from numerous other streams, much carbonate of lime in solution, which contributes to the rapid growth of its delta. A large portion of the most splendid edifices of ancient and modern Rome are built of travertin, derived from the quarries of Ponte Leucano, where there has evidently been a lake at a remote period, on the same plain as that already described. But as the consideration of these would carry us beyond the times of history, we shall conclude with one more example of the calcareous deposits of this neighbourhood,—those on the Anio.

Travertin of Tivoli.—The waters of the Anio incrust the reeds which grow on its banks, and the foam of the cataract of Tivoli forms beautiful pendant stalactites; but, on the sides of the deep chasm into which the cascade throws itself, there is seen an extraordinary accumulation of horizontal beds of tufa and travertin, from four to five hundred feet in thickness. The following seems the most probable explanation of their formation in this singular position. The Anio flows through a deep, irregular fissure or gorge in the Apennine limestone, which may have originated from subterranean movements, like many others of which we shall speak when treating of earthquakes. In this deep narrow channel there existed many small lakes, three of which have been destroyed

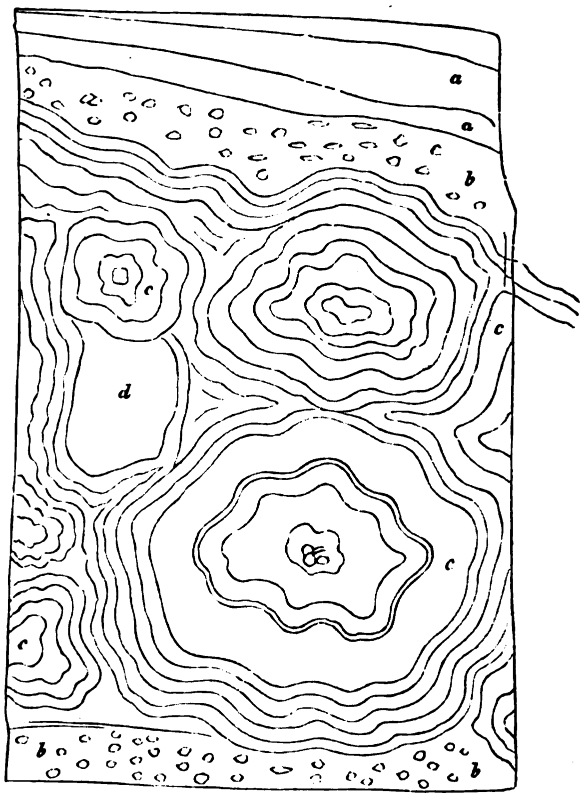
* Consolations in Travel, p. 127.

since the time of history, by the erosive action of the torrent, the last of them having remained down to the sixth century of our era.

We may suppose a similar lake of great depth to have existed at some remote period at Tivoli, and that, into this, the waters, charged with carbonate of lime, fell from a height inferior to that of the present cascade. Having, in their passage through the upper lakes, parted with their sand, pebbles, and coarse sediment, they only introduced into this lower pool drift-wood, leaves, and other buoyant substances. In seasons when the water was low, a deposit of ordinary tufa, or travertin, formed along the bottom; but at other times, when the torrent was swollen, the pool must have been greatly agitated, and every small particle of carbonate of lime which was precipitated must have been whirled round again and again in various eddies, until it acquired many concentric coats, so as to resemble oolitic grains. If the violence of the motion be sufficient to cause the globule to be suspended for a sufficient length of time, it would grow to the size of a pea, or much larger. Small fragments of vegetable stems being incrusted on the sides of the stream, and then washed in, would form the nucleus of oval globules, and others of irregular shapes would be produced by the resting of fragments for a time on the bottom of the basin, where, after acquiring an unequal thickness of travertin on one side, they would again be set in motion. Sometimes globules, projecting above the general level of a stratum, would attract, by chemical affinity, other matter in the act of precipitation, and thus growing on all sides, with the exception of the point of contact, might at length form spheroids nearly perfect and many feet in diameter. Masses might increase above and below, so that a vertical section might afterwards present the phenomenon so common at Tivoli, where the nucleus of some of the concentric circles has the appearance of having been suspended, without support, in the water, until it became a spheroidal mass of great dimensions. The section obtained of these deposits, about four hundred

feet thick, immediately under the temples of Vesta and the Sibyl, displays some spheroids which are from *six to eight feet in diameter*, each concentric layer being about the eighth of an inch in thickness. The annexed diagram exhibits about four-

No. 5.



Section of Spheroidal Concretionary Travertin under the Cascade of Tivoli.

teen feet of this immense mass, as seen in the path cut out of the rock in descending from the temple of Vesta to the Grotto di Nettuno*. The beds (*a a*, diagram No. 5) are of hard tra-

* I have not attempted to express in this drawing the innumerable thin layers of which these magnificent spheroids are composed, but the lines given mark some of the natural divisions into which they are separated by minute variations in the size or colour of the laminæ. The undulations also are much smaller, in proportion to the whole circumference, than is expressed in the diagram.

vertin and soft tufa; below them is a pisolite (*b*), the globules being of different sizes: underneath this appears a mass of concretionary travertin (*cc*), some of the spheroids being of the above-mentioned extraordinary size. In some places (as at *d*) there is a mass of amorphous limestone, or tufa, surrounded by concentric layers. At the bottom is another bed of pisolite (*b*), in which the small nodules are about the size and shape of beans, and some of them of filberts, intermixed with some smaller oolitic grains. In the tufaceous strata, wood is seen converted into a light tufa.

It is probable that the date of the greater portion of this calcareous formation may be anterior to the era of history, for we know that there was a great cascade at Tivoli in very ancient times; but, in the upper part of the travertin, is shown the hollow left by a wheel, in which the outer circle and the spokes have been decomposed, and the spaces which they filled have been left void. It seems impossible to explain the position of this mould, without supposing that the wheel was imbedded before the lake was drained.

Calcareous Springs in the Caucasus.—Our limits do not permit us to enter into minute details respecting the various limestones to which springs in different countries are continually giving birth. Pallas, in his journey along the Caucasus, a country now subject, from time to time, to be rent and fissured by violent earthquakes, enumerates a great many hot springs, which have deposited monticules of travertin precisely analogous in composition and structure to those of the baths of San Filippo and other localities in Italy. When speaking of the tophus-stone, as he terms these limestones, he often observes that it is *snow-white*, a description which is very applicable to the newer part of the deposit at San Filippo, where it has not become darkened by weathering. In many localities in the regions between the Caspian and Black seas, where subterranean convulsions are frequent, travellers mention calc-sinter as an abundant product of hot springs. Near the shores of the Lake Urmia (or Maragha), for example, a marble is rapidly

deposited from a thermal spring, which is much used in ornamental architecture *.

Calcareous deposits.—We might mention springs of the same kind in Calabria and Sicily, and indeed in almost all regions of volcanos and earthquakes which have been carefully investigated. In the limestone districts of England, as on Ingleborough Hill, in Yorkshire, we often see walls entirely constructed of calcareous tufa, enclosing terrestrial shells and vegetables, and similar tufa still continues to be formed in that district. The growth of stalactites, also, and stalagmites in caverns and grottos, is another familiar example of calcareous precipitates. To the solvent power of water, surcharged with carbonic acid, and percolating various winding rents and fissures, we may ascribe those innumerable subterranean cavities and winding passages which traverse the limestone in our own and many other countries. Dr. Buckland has observed, that caves in limestone are usually connected with fissures in the rock in which they exist †.

The quantity of calcareous rock which results from mineral waters in volcanic regions, conspicuous as it is, must be considered as insignificant, in comparison to that which is conveyed by rivers to the sea; and our inability to observe subaqueous accumulations resulting from this source, is one of many causes of our inadequate conception of the changes now in progress on the earth's surface.

Coral reefs of the Pacific.—It has often been supposed, that the greater part of the coral reefs in the Indian and Pacific oceans were based on submarine volcanos,—which seems indicated by the circular shape so frequently assumed by them; but perhaps a still stronger argument in favour of this theory might be deduced from the great abundance of carbonate of lime required for the rapid growth of zoophytic and shelly limestones,—an abundance which could only be looked for where there are active volcanos and frequent earthquakes, as amongst the isles of the South Pacific. We may confidently

* Hoff, Geschichte, &c., vol. ii. p. 114. † Rel. Dil., p. 5, note.

infer, that the development of organic life would be promoted in corals, sponges, and testaceous mollusca, by the heat, carbonic acid, lime, silica, and other mineral ingredients in a state of solution, given out by submarine springs, in the same manner as the vegetation is quickened in the lake of the Solfatara, in the Campagna di Roma, before described.

GYPSEOUS SPRINGS.

All other mineral ingredients wherewith springs in general are impregnated, are insignificant in quantity in comparison to lime, and this earth is most frequently combined with carbonic acid. But as sulphuric acid and sulphuretted hydrogen are very frequently supplied by springs, we must presume that gypsum is now deposited largely in many seas and lakes. The gypseous precipitates, however, hitherto known on the land, appear to be confined to a very few springs. Those at Baden, near Vienna, which feed the public bath, may be cited as examples Some of these supply, singly, from six hundred to one thousand cubic feet of water per hour, and deposit a fine powder, composed of a mixture of sulphate of lime, with sulphur and muriate of lime*.

SILICEOUS SPRINGS.

Azores.—In order that water should hold a very large quantity of silica in solution, it seems necessary that it should be raised to a high temperature †; and as it may retain a greater heat under the pressure of the sea than in the atmosphere, submarine springs may, perhaps, be more charged with silex than any to which we have access. The hot springs of the Valle das Furnas, in the Island of St. Michael, rising through volcanic rocks, precipitate vast quantities of siliceous sinter, as it is usually termed. Around the circular basin of the largest spring, called 'the Caldeira,' which is between twenty and thirty feet in diameter, alternate layers are seen of

* Prevost, Essai sur la Constitution Physique du Bassin de Vienne, p. 10.

† Daubeny, on Volcanos, p. 222.

a coarser variety of sinter mixed with clay, including grass, ferns, and reeds, in different states of petrifaction. Wherever the water has flowed, sinter is found rising in some places eight or ten inches above the ordinary level of the stream. The herbage and leaves, more or less incrusted with silex, exhibit all the successive steps of petrifaction, from the soft state to a complete conversion into stone; but, in some instances, alumina, which is likewise deposited from the hot waters, is the mineralizing material. Branches of the same ferns which now flourish in the island, are found completely petrified, preserving the same appearance as when vegetating, except that they acquire an ash-gray colour. Fragments of wood, and one entire bed from three to five feet in depth, composed of reeds now common in the island, have become completely mineralized.

The most abundant variety of siliceous sinter occurs in layers from a quarter to half an inch in thickness, accumulated on each other often to the height of a foot and upwards, and constituting parallel, and for the most part horizontal, strata many yards in extent. This sinter has often a beautiful semi-opalescent lustre. One of the varieties differs from that of Iceland and Ischia in the larger proportion of water it contains, and in the absence of alumina and lime. A recent breccia is also in the act of forming, composed of obsidian, pumice, and scoriæ, cemented by siliceous sinter *.

Geysers of Iceland.—But the hot springs in various parts of Iceland, particularly the celebrated geysers, afford the most remarkable example of the deposition of silex. The circular reservoirs into which the geysers fall, are filled in the middle with a variety of opal, and round the edges with sinter. The plants, incrusted with the latter substance, have much the same appearance as those incrusted with calcareous tufa in our own country. The solution of the silex is supposed to be promoted by the presence of some mineral alkali. In some of the thermal waters of Iceland a vesicular rock is formed, containing portions of vegetables, more or less completely silicified. Amongst

* Dr. Webster, on the Hot Springs of Furnas, Ed. Phil. Journ. vol. vi. p. 306.

the various products also of springs in this island, is that admixture of clay and silica, called tripoli.

Ischia.—It has been found, by recent analysis, that several of the thermal waters of Ischia are impregnated with a certain proportion of silica. Some of the hot vapours of that island are above the temperature of boiling water; and many fissures, near Monte Vico, through which the hot steam passes, are coated with a siliceous incrustation, first noticed by Dr. Thompson under the name of fiorite.

Ava, &c.—It has been often stated that the Danube has converted the external part of the piles of Trajan's bridge into silex; the Irawadi, in Ava, has been supposed, ever since the time of the Jesuit Padre Duchatz, to have the same petrifying power, as has also Lough Neagh, in Ireland. Modern researches, however, in the Burman empire, have thrown doubt upon the lapidifying property of the Ava river*; there is certainly no foundation for the story in regard to Lough Neagh, and probably none in regard to the Danube.

Mineral waters, even when charged with a small proportion of silica, as those of Ischia, may supply certain species of corals and sponges with matter for their siliceous secretions; but when in a volcanic archipelago, or a region of submarine volcanos, there are springs so saturated with silica, as those of Iceland and the Azores, we may expect beds of chert or layers and nodules of silex, to be spread out far and wide over the bed of the sea, and interstratified with shelly and calcareous deposits, which may be forming there, or with matter derived from the wasting cliffs or volcanic ejections.

FERRUGINOUS SPRINGS.

The waters of almost all springs contain some iron in solution; and it is a fact familiar to all, that many of them are so copiously impregnated with this metal, as to stain the rocks or herbage through which they pass, and to bind together sand

* Dr. Buckland, Geol. Trans., second series, vol. ii. part 3, p. 384.

and gravel into solid masses. We may naturally, therefore, conclude that this iron, which is constantly conveyed into lakes and seas from the interior of the earth, and not returned again to the land by evaporation in the atmospheric waters, must act as a colouring and cementing principle in the subaqueous deposits now in progress. When we find, therefore, that so many sandstones and other rocks in the sedimentary strata of ancient lakes and seas are bound together or coloured by iron, it presents us with a striking point of analogy between the state of things at very different epochs. In the older formations we meet with great abundance of carbonate and sulphate of iron; and in chalybeate waters at present, this metal is most frequently in the state of a carbonate, as in those of Tunbridge, for example. Sulphuric acid, however, is often the solvent, which is in many cases derived from the decomposition of pyrites.

BRINE SPRINGS.

Cheshire.—So great is the quantity of muriate of soda in some springs, that they yield one-fourth of their weight in salt. They are rarely, however, so saturated, and generally contain, intermixed with salt, carbonate and sulphate of lime, magnesia, and other mineral ingredients. The brine springs of Cheshire are the richest in our country; those of Barton and Northwich being almost fully saturated. These brine springs rise up through strata of sandstone and red marl, which contain large beds of rock-salt. The origin of the brine, therefore, may be derived in this and many other instances from beds of fossil salt; but as muriate of soda is one of the products of volcanic emanations and of springs in volcanic regions, the original source of salt may be as deep seated as that of lava.

Dead Sea.—The waters of the Dead Sea contain scarcely anything except muriatic salts, which lends countenance, observes Dr. Daubeny, to the volcanic origin of the surrounding country, these salts being frequent products of volcanic erup-

tions. Many springs in Sicily contain muriate of soda, and the 'fiume salso,' in particular, is impregnated with so large a quantity, that cattle refuse to drink of it. If rivers or springs, thus impregnated, enter a lake or estuary, it is evident that they may give rise to partial precipitates of salt.

Auvergne.—A hot spring, rising through granite, at Saint Nectaire, in Auvergne, may be mentioned as one of many, containing a large proportion of muriate of soda, together with magnesia and other ingredients *.

CARBONATED SPRINGS.

Auvergne.—Carbonic acid gas is very plentifully disengaged from springs in almost all countries, but particularly near active or extinct volcanos. This elastic fluid has the property of decomposing many of the hardest rocks with which it comes in contact, particularly that numerous class in whose composition felspar is an ingredient. It renders the oxide of iron soluble in water, and contributes, as was before stated, to the solution of calcareous matter. In volcanic districts these gaseous emanations are not confined to springs, but rise up in the state of pure gas from the soil in various places. The Grotto delle Cane, near Naples, affords an example, and prodigious quantities are now annually disengaged from every part of the Limagne d'Auvergne, where it appears to have been developed in equal quantity from time immemorial. As the acid is invisible, it is not observed, except an excavation be made, wherein it immediately accumulates, so that it will extinguish a candle. There are some springs in this district, where the water is seen bubbling and boiling up with much noise, in consequence of the abundant disengagement of this gas. The whole vegetation is affected, and many trees, such as the walnut, flourish more luxuriantly than they would otherwise do in the same soil and climate,—the leaves probably absorbing carbonic acid. This gas is found in springs rising through the granite near Clermont, as well as in the tertiary

* Annales de l'Auvergne, tome i. p. 234.

limestones of the Limagne *. In the environs of Pont-Gibaud, not far from Clermont, a rock belonging to the gneiss formation, in which lead-mines are worked, has been found to be quite saturated with carbonic acid gas, which is constantly disengaged. The carbonates of iron, lime, and manganese are so dissolved, that the rock is rendered soft, and the quartz alone remains unattacked †. Not far off is the small volcanic cone of Chaluzet, which once broke up through the gneiss, and sent forth a lava-stream.

Disintegration of granite.—The disintegration of granite is a striking feature of large districts in Auvergne, especially in the neighbourhood of Clermont. This decay was called by Dolomieu, 'la maladie du granite;' and the rock may with propriety be said to have *the rot*, for it crumbles to pieces in the hand. The phenomenon may, without doubt, be ascribed to the continual disengagement of carbonic acid gas from numerous fissures.

In the plains of the Po, between Verona and Parma, especially at Villa Franca, south of Mantua, I observed great beds of alluvium, consisting chiefly of primary pebbles percolated by spring water, charged with carbonate of lime and carbonic acid in great abundance. They are for the most part incrusted with calc-sinter; and the rounded blocks of gneiss, which have all the appearance of solidity, have been so disintegrated by the carbonic acid as readily to fall to pieces. The Po and other rivers, in winding through this plain, might now remove with ease those masses which, at a more remote period, the stream was unable to carry farther towards the sea; and in this example we may perceive how necessary it is, in reasoning on the transporting power of running water, to consider all the numerous agents which may co-operate, in the lapse of ages, in conveying the wreck of mountains to the sea. A granite block might remain stationary for ages, and defy

* Le Coq, Annales de l'Auvergne, tome i. p. 217. May, 1828.

† Ann. Scient. de l'Auvergne, tome ii. June, 1829.

the power of a large river; till at length a small spring may break out, surcharged with carbonic acid,—the rock may be decomposed, and a streamlet may transport the whole mass to the ocean.

The subtraction of many of the elements of rocks by the solvent power of carbonic acid, ascending both in a gaseous state and mixed with spring-water in the crevices of rocks, must be one of the most powerful sources of those internal changes and re-arrangements of particles so often observed in strata of every age. The calcareous matter, for example, of shells is often entirely removed and replaced by carbonate of iron, pyrites, or silex, or some other ingredient, such as mineral waters usually contain in solution. It rarely happens, except in limestone rocks, that the carbonic acid can dissolve all the constituent parts of the mass; and for this reason, probably, calcareous rocks are almost the only ones in which great caverns and long winding passages are found. The grottos and subterranean passages in certain lava-currents are due to a different cause, and will be spoken of in another place.

PETROLEUM SPRINGS.

Springs impregnated with petroleum, and the various minerals allied to it, as bitumen, naphtha, asphaltum, and pitch, are very numerous, and are, in many cases, undoubtedly connected with subterranean fires, which raise or sublime the more subtle parts of the bituminous matters contained in rocks. Many springs in the territory of Modena and Parma, in Sicily, produce petroleum in abundance; but the most powerful, perhaps, yet known, are those on the Irawadi, in the Burman empire. In one locality there are said to be five hundred and twenty wells, which yield annually four hundred thousand hogsheads of petroleum*.

* Symes, Embassy to Ava, vol. ii.—Geol. Trans., Second Series, vol. ii. part iii. p. 388,

Fluid bitumen is seen to ooze from the bottom of the sea, on both sides of the island of Trinidad, and to rise up to the surface of the water. Near Cape La Braye there is a vortex which, in stormy weather, according to Captain Mallet, gushes out, raising the water five or six feet, and covers the surface for a considerable space with petroleum, or tar; and the same author quotes Gumilla, as stating in his 'Description of the Orinoco,' that, about seventy years ago, a spot of land on the western coast of Trinidad, near half-way between the capital and an Indian village, sank suddenly, and was immediately replaced by a small lake of pitch, to the great terror of the inhabitants *.

Pitch lake of Trinidad.—It is probable that the great pitch lake of Trinidad owes its origin to a similar cause; and Dr. Nugent has justly remarked, that in that district all the circumstances are now combined from which deposits of pitch may have originated. The Orinoco has for ages been rolling down great quantities of woody and vegetable bodies into the surrounding sea, where, by the influence of currents and eddies, they may be arrested and accumulated in particular places. The frequent occurrence of earthquakes and other indications of volcanic action in those parts lend countenance to the opinion, that these vegetable substances may have undergone, by the agency of subterranean fire, those transformations and chemical changes which produce petroleum, and may, by the same causes, be forced up to the surface, where, by exposure to the air, it becomes inspissated, and forms the different varieties of pure and earthy pitch, or asphaltum, so abundant in the island †.

The bituminous shales, so common in geological formations of different ages, as well as many stratified deposits of bitumen and pitch, seem clearly to attest that, at former periods, springs, in various parts of the world, were as commonly impregnated as now with bituminous matter, which was carried

* Dr. Nugent, Geol. Trans., vol. i. p. 69. † Ibid., p. 67.

down by rivers into lakes and seas. We may indeed remark generally, that a large portion of the finer particles and the more crystalline substances found in sedimentary rocks of different ages are composed of the same elements as are now held in solution by springs, while the coarser materials bear an equally strong resemblance to the alluvial matter in the beds of existing torrents and rivers.

CHAPTER XIII.

Reproductive effects of running water—Division of Deltas into lacustrine, mediterranean, and oceanic—Lake deltas—Growth of the delta of the Rhone in the Lake of Geneva—Chronological computations of the age of deltas—Recent deposits in Lake Superior—Deltas of inland seas—Rapid shallowing of the Baltic—Arguments for and against the hypothesis of Celsius—Elevated beaches on the coast of Sweden—Marine delta of the Rhone—Various proofs of its increase—Stony nature of its deposits—Delta of the Po, Adige, Isonzo, and other rivers entering the Adriatic—Rapid conversion of that gulf into land—Mineral characters of the new deposits—Delta of the Nile—Its increas since the time of Homer—Its growth why checked at present.

REPRODUCTIVE EFFECTS OF RUNNING WATER.

We have hitherto considered the destroying agency of running water, as exhibited in the disintegration of rocks and transportation of matter from higher to lower levels. It remains for us to examine the reproductive effects of the same cause. The aggregate amount of matter accumulated in a given time at the mouths of rivers, where they enter lakes or seas, affords clearer data for estimating the energy of the excavating power of running water on the land, than the separate study of the operations of the same cause in the countless ramifications into which every great system of valleys is divided. We shall proceed to select some of the leading facts at present ascertained respecting the growth of deltas, and shall then offer some general observations on the quantity of subaqueous sediment transported by rivers, and on the manner of its distribution.

Division of deltas into lacustrine, mediterranean, and oceanic.—Deltas may be divided into, first, those which are formed in lakes; secondly, those formed in inland seas; and thirdly, those formed on the borders of the ocean. The most characteristic distinction between the lacustrine and marine deltas consists in the nature of the organic remains, which become imbedded in their deposits, for, in the case of a lake,

it is obvious that these must consist exclusively of such genera of animals as inhabit the land or the waters of a river or lake; whereas, in the other case, there will be an admixture and most frequently a predominance of animals which inhabit salt water. In regard, however, to the distribution of inorganic matter, the deposits of lakes and inland seas are formed under very analogous circumstances and may be contradistinguished from those on the shores of the great ocean, where the tides cooperating with currents give rise to a distinct class of phenomena. In lakes and inland seas, even of the largest dimensions, the tides are almost insensible, and the currents are, for the most part, inconsiderable, although some striking exceptions to this rule will be mentioned when we treat of tides and currents.

DELTAS IN LAKES.

Lake of Geneva.—It is natural to begin our examination with an inquiry into the new deposits in lakes, as they exemplify the first reproductive operations in which rivers are engaged when they convey the detritus of rocks and the ingredients of mineral springs from mountainous regions. The accession of new land at the mouth of the Rhone, at the upper end of the Lake of Geneva, or the Leman Lake, presents us with an example of a considerable thickness of strata, which have accumulated since the historical era. This sheet of water is about thirty-seven miles long, and its breadth is from two to eight miles. The shape of the bottom is very irregular, the depth having been found, by late measurements, to vary from twenty to one hundred and sixty fathoms *. The Rhone, where it enters at the upper end, is turbid and discoloured; but its waters, where it issues at the town of Geneva, are beautifully clear and transparent. An ancient town, called Port Vallais, (Portus Valesiæ of the Romans,) once situated at the water's edge, at the upper end, is now more than a mile and a half inland,—this intervening alluvial tract having been

* De la Beche, Ed. Phil. Journ., vol. ii. p. 107, Jan. 1820.

acquired in about eight centuries. The remainder of the delta consists of a flat alluvial plain, about five or six miles in length, composed of sand and mud, a little raised above the level of the river and full of marshes.

Mr. De la Beche found, after numerous soundings in all parts of the lake, that there was a pretty uniform depth of from one hundred and twenty to one hundred and sixty fathoms throughout the central region, and, on approaching the delta, the shallowing of the bottom began to be very sensible at a distance of about a mile and three-quarters from the mouth of the Rhone; for a line drawn from St. Gingoulph to Vevey, gives a mean depth of somewhat less than six hundred feet, and from that part to the Rhone, the fluviatile mud is always found along the bottom *. We may state, therefore, that the strata annually produced are about two miles in length: so that, notwithstanding the great depth of the lake, the new deposits are not inclined at a high angle; the dip of the beds, indeed, is so slight, that they would be termed, in ordinary geological language, horizontal.

The strata probably consist of alternations of finer and coarser particles, for, during the hotter months from April to August, when the snows melt, the volume and velocity of the river are greatest, and large quantities of sand, mud, vegetable matter, and drift-wood are introduced; but, during the rest of the year, the influx is comparatively feeble, so much so, that the whole lake, according to Saussure, stands six feet lower. If, then, we could obtain a section of the accumulation formed in the last eight centuries, we should see a great series of strata, probably from six to nine hundred feet thick, and nearly two miles in length, inclined at a very slight angle. In the mean time, a great number of smaller deltas are growing around the borders of the lake, at the mouths of rapid torrents, which pour in large masses of sand and pebbles. The body of water in these torrents is too small to enable them to spread out the transported matter over so extensive an area as the Rhone.

* De la Beche, MS.

Thus, for example, there is a depth of eighty fathoms within half a mile of the shore, immediately opposite the great torrent which enters east of Ripaille, so that the dip of the strata in that delta is about four times as great as those deposited by the main river at the upper extremity of the lake *.

Chronological computations of the age of deltas.—The capacity of this basin being now ascertained, it would be an interesting subject of inquiry, to determine in what number of years the Leman Lake will be converted into dry land. It would not be very difficult to obtain the elements for such a calculation, so as to approximate at least to the quantity of time required for the accomplishment of this result. The number of cubic feet of water annually discharged by the river into the lake being estimated, experiments might be made in the winter and summer months, to determine the proportion of matter held in suspension or in chemical solution by the Rhone. It would be also necessary to allow for the heavier matter drifted along at the bottom, which might be estimated on hydrostatical principles, when the average size of the gravel and the volume and velocity of the stream at different seasons were known. Supposing all these observations to have been made, it would be more easy to calculate the future than the former progress of the delta, because it would be a laborious task to ascertain, with any degree of precision, the original depth and extent of that part of the lake which is already filled up. Even if this information were actually obtained by borings, it would only enable us to approximate within a certain number of centuries to the time when the Rhone began to form its present delta; but this would not give us the date of the origin of the Leman Lake in its present form, because the river may have flowed into it for thousands of years, without importing any sediment whatever. Such would have been the case, if the waters had first passed through a chain of upper lakes; and that this was actually the fact, is indicated by the course of the Rhone between Martigny and the Lake

* De la Beche, MS.

of Geneva, and still more decidedly, by the channels of many of its principal feeders.

If we ascend, for example, the valley through which the Dranse flows, we find that it consists of a succession of basins, one above the other, in each of which there is a wide expanse of flat alluvial lands, separated from the next basin by a rocky gorge, once evidently the barrier of a lake. The river has filled the lake, and partially cut through the barrier, which it is still gradually eroding to a greater depth. The examination of almost all valleys in mountainous districts affords abundant proofs of the obliteration of a series of lakes, by the filling up of hollows and the cutting through of rocky barriers—a process by which running water ever labours to produce a more uniform declivity. Before, therefore, we can pretend even to hazard a conjecture as to the era at which any particular delta commenced, we must be thoroughly acquainted with the geologica. history of the whole system of higher valleys which communicate with the main stream, and all the changes which they have undergone since the last series of convulsions which agitated and altered the face of the country.

The probability, therefore, of error in our chronological computations, where we omit to pay due attention to these circumstances, increases in proportion to the time that may have elapsed since the last disturbance of the country by subterranean movements, and in proportion to the extent of the hydrographical basin on which we may happen to speculate. The Alpine rivers of Vallais are prevented at present from contributing their sedimentary contingent to the delta of the Rhone in the Mediterranean, because they are intercepted by the Leman Lake; but when this is filled, they will transport as much, or nearly as much, matter to the sea as they now pour into that lake. They will then flow through a long, flat, alluvial plain, between Villeneuve and Geneva, from two to eight miles in breadth, which will present no superficial marks of the existence of a thickness of more than one thousand feet of recent sediment below. Many hundred alluvial tracts of equal,

and some of much greater area, may be seen if we follow up the Rhone from its mouth, or explore the valleys of many of its principal tributaries.

What, then, shall we think of the presumption of De Luc, Kirwan, and their followers, who confidently deduced from the phenomena of modern deltas the recent origin of the present form of our continents, without pretending to have collected any one of the numerous data by which so complicated a problem can be solved? Had they, after making all the necessary investigations, succeeded in proving, as they desired, that the delta of the Rhone, and the new deposits at the mouths of all other rivers, whether in lakes or seas, had required about four thousand years to attain their present dimensions, the conclusion would have been fatal to the chronological theories, which they were anxious to confirm. The popular reception of these, and similar sophisms, respecting the effects of causes in diurnal action has hitherto thrown stumbling-blocks in the way of those geologists who desire to pursue the science according to the rules of inductive philosophy. If speculations so vague and visionary can be proposed concerning natural operations now passing before our eyes—if authors may thus dogmatize, with impunity, on subjects capable of being determined with a considerable degree of precision, can we be surprised that they who reason on the more obscure phenomena of remote ages, should wander in a maze of error and inconsistency?

The Leman Lake fills a great cavity in rocky strata, composed of a tertiary conglomerate and sand, which constitutes its bottom, almost all its northern banks, and a great part of its southern or Alpine side. It has often been asked, why this cavity has not been filled up by the detritus of rocks, removed from the numerous valleys now drained by the waters which enter the lake? In order to remove this difficulty, it would be necessary to enter into a description of the strata of different ages composing the Alps and the Subalpine districts; to point out the distinct periods of their elevation above the sea, and the pre-existence of many mountain valleys, even to the for-

mation of those deposits wherein the Lake of Geneva is contained. It would be premature, therefore, to enter upon this subject at present, to which we shall revert when we have described the phenomena of some of the ancient strata.

Lake Superior.—Lake Superior is the largest body of fresh water in the world, being about one thousand five hundred geographical miles in circumference, if we follow the sinuosities of its coasts, its length, on a curved line through its centre, being about three hundred and sixty, and its extreme breadth one hundred and forty geographical miles. Its average depth varies from eighty to one hundred and fifty fathoms; but, according to Captain Bayfield, there is reason to think that its greatest depth would not be overrated at two hundred fathoms *, so that its bottom is, in some parts, nearly six hundred feet below the level of the Atlantic, as its surface is about as much above it. There are appearances in different parts of this, as of the other Canadian lakes, leading us to infer that its waters have formerly occupied a much higher level than they reach at present; for at a considerable distance from the present shores, parallel lines of rolled stones and shells are seen rising one above the other, like the seats of an amphitheatre. These ancient lines of shingle are exactly similar to the present beaches in most bays, and they often attain an elevation of forty or fifty feet above the present level.

As the heaviest gales of wind do not raise the waters more than three or four feet †, the elevated beaches must either be referred to the subsidence of the lake at former periods, in consequence of the wearing down of its barrier, or to the upraising of the shores by earthquakes, like those which have produced similar phenomena on the coast of Chili. But there seem to be no facts which lend countenance to the latter hypothesis, in

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5, 1829.

† Captain Bayfield remarks, that Dr. Bigsby, to whom we are indebted for several communications respecting the geology of the Canadian lakes, was misinformed by the fur traders in regard to the extraordinary height (twenty or thirty feet) to which he asserts that the autumnal gales will raise the water of Lake Superior.—Ibid., p. 7.

reference to the North American lakes. The streams which discharge their waters into Lake Superior are several hundred in number, without reckoning those of smaller size; and the quantity of water supplied by them is many times greater than that discharged at the Falls of St. Mary, the only outlet. The evaporation, therefore, is very great, and such as might be expected from so vast an extent of surface.

On the northern side, which is encircled by primary mountains, the rivers sweep in many large boulders with smaller gravel and sand, chiefly composed of granitic and trap rocks. There are also currents in the lake, in various directions, caused by the continued prevalence of strong winds, and to their influence we may attribute the diffusion of finer mud far and wide over great areas; for, by numerous soundings made during the late survey, it was ascertained that the bottom consists generally of a very adhesive clay, containing shells of the species at present existing in the lake. When exposed to the air, this clay immediately becomes indurated in so great a degree, as to require a smart blow to break it. It effervesces slightly with diluted nitric acid, and is of different colours in different parts of the lake; in one district blue, in another red, and in a third white, hardening into a substance resembling pipe-clay *. From these statements, the geologist will not fail to remark how closely these recent lacustrine formations in America resemble the tertiary argillaceous and calcareous marls of lacustrine origin in Central France. In both cases, many of the genera of shells most abundant, as Lymnea and Planorbis, are the same; and in regard to other classes of organic remains, there must be the closest analogy, as we shall endeavour more fully to explain when speaking of the imbedding of plants and animals in recent deposits.

DELTAS OF INLAND SEAS.

Supposed diminution of level in the Baltic.—Having offered

* Trans. of Lit. and Hist. Soc. of Quebec, vol. i. p. 5, 1829.

these few remarks on lacustrine deltas now in progress, we may next turn our attention to those of inland seas.

The shallowing and conversion into land of many parts of the Baltic, especially the Gulfs of Bothnia and Finland, have been demonstrated by a series of accurate observations, for which we are in a great measure indebted to the animated controversy which has been kept up, since the middle of the last century, concerning the gradual lowering of the level of the Baltic. Celsius, the Swedish astronomer, first originated the idea, that from the earliest times there had been a progressive fall of about forty-five inches in a century, in the mean level of the waters of that sea. He contended that this change rested not only on modern observations, but on the authority of the ancient geographers, who stated that Scandinavia was formerly an island. By the gradual depression of the sea, he said, that great island became connected with the continent; and that this event happened after the time of Pliny, and before the ninth century of our era.

To the arguments urged in support of these positions, his opponents objected that the ancients were so ignorant of the geography of the most northern parts of Europe, that their authority was entitled to no weight; and that their representation of Scandinavia as an island, might with more propriety be adduced to prove the scantiness of their information, than to confirm so bold an hypothesis. It was also remarked that if the land which connected Scandinavia with the main continent was laid dry between the time of Pliny and the ninth century, to the extent to which it is known to have risen above the sea at the latter period, the rate of depression could not have been uniform, as was pretended, for it ought to have fallen much more rapidly between the ninth and eighteenth century.

Many of the physical proofs relied on by Celsius and his followers show clearly that they did not distinguish between the shallowing of the water by deposition of fresh sediment, and the diminution of depth caused by subsidence of the sea. By their own statements, it appeared that the accessions of new

land, and the loss of depth, were at the mouths of rivers, or in certain deep bays, into which it is well known that sand and mud are carried by currents. As illustrating, however, the gradual conversion of the Gulf of Bothnia into land, their observations deserve great attention. Thus, for example, they pointed out the fact, that at Pitea half a mile was gained in forty-five years, and at Lulea no less than a mile in twenty-eight years. Ancient ports on the same coast had become inland cities. Considerable tracts of the gulf were rendered three feet shallower in the course of fifty years—many old fishing-grounds had been changed into dry land—small islands had been joined to the continent. According to Linnæus, the increase of land on the eastern side of Gothland, near Hoburg, was about two or three toises annually for ninety years*.

Besides these changes, it was asserted that, along the southern shore also of the Baltic, particularly in West Prussia and Pomerania, anchors and sunk ships had been discovered far inland; and although these occurrences were partly accounted for by the silting up of river-beds, yet the tradition seems worthy of credit, that a bay of the sea penetrated, at a remote period, much farther to the south in that direction. These, and many other facts, are of geological interest, although they afford no confirmation to the theory of Celsius.

His most plausible arguments were derived from the alleged exposure of certain insular rocks in the Bothnian and other bays, which were declared to have been once entirely covered with water, but which had gradually protruded themselves more and more above the waves, until, in the course of about a century and a half, they grew to be eight feet high. Of this phenomenon the following explanation was offered by his opponents. The islands in question consisted of sand and drift-stones, and the waves, during great tempests, threw up new matter upon them, or converted shoals into islands. Sometimes, also, icebergs, heavily laden with rock, were

* Linn. de tell. habit. increm.

stranded on a shoal or driven up on a low island; and when they melted away, they left a mass of debris, many feet in height.

Browallius, and other Swedish naturalists, pointed out that some of these islands were lower than formerly; so that, by reference to this kind of evidence, there was equally good reason for contending that the level of the Baltic was gradually rising. They also added another curious and very conclusive proof of the permanency of the water-level for many centuries. On the Finland coast were some large pines, growing close to the water's edge; these were cut down, and, by counting the concentric rings of annual growth, as seen in a transverse section of the trunk, it was demonstrated that they had stood there for four hundred years. Now, according to the Celsian hypothesis, the sea had sunk fifteen feet during that period, so that the germination and early growth of these pines must have been for many seasons below the level of the water. In like manner it was shown, that the lower walls of many ancient castles, such as those of Sonderburg and Abo, reached then to the water's edge, and must, therefore, according to the theory of Celsius, have been originally constructed below the level of the sea.

Another unanswerable argument in proof of the stability of the level of the Baltic was drawn from the island of Saltholm, not far from Copenhagen. This isle is so low that, in autumn and winter, it is permanently overflowed; and it is only dry in summer, when it serves for pasturing cattle. It appears, from documents of the year 1280, that this island was then also in the same state, and exactly on a level with the mean height of the sea, instead of being twenty feet under water, as it ought to have been according to the computation of Celsius. Several towns, also, on the shores of the Baltic, as Lubeck, Wismar, Rostock, Stralsund, and others, after six and even eight hundred years, are as little elevated above the sea as at the era of their foundation, being now close to the water's edge. The lowest part of Dantzic was no higher than the mean level of

the sea in the year 1000; and after eight centuries its relative position remains exactly the same *.

Notwithstanding these convincing proofs that the supposed change in the relative level of land and sea arose from some local appearances, there are still many who contend for a lowering of the Baltic; and many Swedish officers of the pilotage establishment declared, in the year 1821, in favour of this opinion, after measuring the height of landmarks placed at certain heights above the sea half a century before, as objects of comparison, for the express purpose of settling the point at issue. Before we attach any weight to these assertions, which only relate to slight differences of elevation, we ought to be assured that the observers were on their guard against every imaginable cause of deception arising from local circumstances. Thus, for example, if the height of an alluvial plain was taken during the last century, it might have been subsequently raised by fresh deposits, and thus the sea would appear to have sunk; or, if a mark was cut in the rocks, the sea may have been several inches or even feet higher at one period than another, in consequence of the setting in of a current urged by particular winds into a long narrow gulf, which cause is well known to raise the Baltic, at some seasons, two feet above its ordinary level.

It is however possible that this inland sea, filled as it is with river-water, and, unlike the Mediterranean, discharging into the ocean more water than it receives from it, may resemble the estuary of a great river, rising many feet above the mean level of the ocean. In this case, the Baltic may have gradually lowered its level during several successive centuries, in proportion as it obtained a freer efflux, occasioned by the widening of the channel of discharge during encroachments of the German ocean.

Elevated beaches in Sweden.—Von Buch, in his travels, discovered in Norway, and at Uddevalla in Sweden, beds of shells

* For a full account of the Celsian controversy, we may refer our readers to Von Hoff, Geschichte, &c., vol. i. p. 439.

of existing species at considerable heights above the level of the water. Since that time, several other naturalists have confirmed his observation; and, according to Ström, some deposits occur at an elevation of more than four hundred feet above the sea in the northern part of Norway. M. Alex. Brongniart, who has lately visited Uddevalla in Gotheborg, a port at the entrance of the Baltic, informs us that the principal mass of shells in the creek of Uddevalla rises about two hundred feet above the level of the sea, resting on rocks of gneiss. All the species are identical with those now inhabiting the contiguous sea, and are for the most part entire, although some of them are broken, as happens on a sea-beach. They are nearly free from any admixture of earthy matter. The reader need scarcely be reminded that, at the height of a few feet above the beach, on our coasts, the rocks, where they are alternately submerged and laid dry by the ebbing and flowing tide, are frequently covered with barnacles or balani, which are firmly attached. On examining with care the smooth surface of the gneiss, immediately above the ancient shelly beach at Uddevalla, M. Brongniart found, in a similar manner, balani adhering to the rocks, so that there can be no doubt that the sea had for a long period sojourned on the spot*.

Now, this interesting fact is precisely analogous to one well known to all who are acquainted with the geology of the borders of the Mediterranean. Perforating testacea of the genus Lithodomus, Cuv., excavate funnel-shaped hollows in the hardest limestone and marble, along the present sea-shores; and lines of these perforations, sometimes containing the same species of shells, have been discovered at various heights above the sea near Naples, in Calabria, at Monte Pelegrino, in the Bay of Palermo, and other localities. As many of these districts have been violently shaken by earthquakes within the historical era, and as the land has been sometimes raised and sometimes depressed, as we shall afterwards show by examples, there is no difficulty in explaining the pheno-

* Tableau des Terrains, &c., p. 89. 1829.

mena, provided time be allowed. But no argument can be derived, from such observations, in support of great upheavings of the coast, whether by slow or sudden operations in modern times, unless we use the term *modern* in a geological sense. On the contrary, we know that the physical outline of the coast and heights in the bay of Palermo, when it was a Greek port, more than two thousand years ago, was so nearly the same as it is at present, that the beds of recent shells, and the perforations in the rocks, must have stood nearly in the same relation to the level of the Mediterranean as they stand now,

The high beaches on the Norwegian and Swedish coast establish the important and certainly very unexpected fact, that those parts of Europe have been the theatres of considerable subterranean movements within the present zoological era, or since the seas were inhabited by species now our contemporaries. But the phenomena do not lend the slightest support to the Celsian hypothesis, nor to that extraordinary notion proposed in our own times by Von Buch, who imagines that the whole of the land along the northern and western shores of the Baltic is slowly and insensibly rising! No countries have been more entirely free from earthquakes since the times of authentic history than Norway, Sweden, and Denmark. In common with our own island, and, indeed, with almost every spot on the globe, they have experienced some slight shocks at certain periods, as during the earthquake of Lisbon, and on a few other occasions, but these may rather be considered as prolonged vibrations in the crust of the earth, extending in the manner of sounds through the air to almost indefinite distances, than as those violent movements which in the great regions of active volcanos change, from time to time, the relative level of the land and sea.

Delta of the Rhone.—We may now turn our attention to some of the principal deltas of the Mediterranean, for no other inland sea affords so many examples of accessions of new lands at the mouths of rivers within the records of authentic history. We have already considered the lacustrine delta of the Rhone

in Switzerland, and we shall now describe its contemporaneous marine delta. Scarcely has the river passed out of the Leman Lake, before its pure waters are again filled with sand and sediment by the impetuous Arve, descending from the highest Alps, and bearing along in its current the granitic detritus annually carried down by the glaciers of Mont Blanc. The Rhone afterwards receives vast contributions of transported matter from the Alps of Dauphiny, and the primary and volcanic mountains of Central France; and when at length it enters the Mediterranean, it discolours its blue waters with a whitish sediment for the distance of between six and seven miles from its mouth, throughout which space the current of fresh-water is perceptible.

Proofs of its increase since historical period.—Strabo's description of the delta is so inapplicable to its present configuration, as to attest a complete alteration in the physical features of the country since the Augustan age. It appears, however, that the head of the delta, or the point at which it begins to ramify, has remained unaltered since the time of Pliny, for he states that the Rhone divided itself at Arles into two arms. This is the case at present; one of the branches being now now called Le petit Rhône, which is again subdivided before entering the Mediterranean. The advance of the base of the delta, in the last eighteen centuries, is demonstrated by many curious antiquarian monuments. The most striking of these is the great detour made by the old Roman road from Ugernum to Beziers (part of the high road between Aix, Aquæ Sextiæ, and Nismes, Nemausus). It is clear that, when this was first constructed, it was impossible to pass in a direct line, as now, across the delta, and that either the sea or marshes intervened in a tract now consisting of terra firma *. Astruc also remarks, that all the places on the low lands, lying to the north of the old Roman road between Nismes and Beziers, have names of Celtic origin evidently given to them by the first inhabitants of the country; whereas the places lying south of

* Mem. d'Astruc, cited by Von Hoff, vol. i. p. 228.

that road, towards the sea, have names of Latin derivation, and were clearly founded after the Roman language had been introduced.

Another proof, also, of the great extent of land which has come into existence since the Romans conquered and colonized Gaul, is derived from the fact, that the Roman writers never mention the thermal waters of Balaruc in the delta, although they were well acquainted with those of Aix and others, still more distant, and attached great importance to them, as they invariably did to all hot springs. The waters of Balaruc, therefore, must have formerly issued under the sea—a common phenomenon on the borders of the Mediterranean; and on the advance of the delta they continued to flow out through the new deposits.

Among the more direct proofs of the increase of land, we find that Mese, described under the appellation of Mesua Collis by Pomponius Mela*, and stated by him to be nearly an island, is now far inland. Notre Dame des Ports, also, was a harbour in 898, but is now a league from the shore. Psalmodi was an island in 815, and is now two leagues from the sea. Several old lines of towers and sea-marks occur at different distances from the present coast, all indicating the successive retreat of the sea, for each line has in its turn become useless to mariners, which may well be conceived, when we state that the tower of Tignaux, erected on the shore so late as the year 1737, is already a French mile remote from it †.

By the confluence of the Rhone and the currents of the Mediterranean driven by winds from the south, sand-bars are often formed across the mouths of the river: by these means considerable spaces become divided off from the sea, and subsequently from the river also, when it shifts its channels of efflux. As some of these lagoons are subject to the occasional ingress of the river when flooded, and of the sea during storms, they are alternately salt and fresh. Others, after being filled

* Lib. II., c. v.

† Bouche, Chorographie et Hist. de Provence, vol. i. p. 23, cited by Hoff, vol. i. p. 290.

with salt-water, are often lowered by evaporation till they become more salt than the sea; and it has happened, occasionally, that a considerable precipitate of muriate of soda has taken place in these natural salterns. During the latter part of Napoleon's career, when the excise-laws were enforced with extreme rigour, the police was employed to prevent such salt from being used. The fluviatile and marine shells enclosed in these small lakes often live together in brackish water; but the uncongenial nature of the fluid usually produces a dwarfish size, and sometimes gives rise to strange varieties in form and colour.

Captain Smyth, in the late survey of the coast of the Mediterranean, found the sea, opposite the mouth of the Rhone, to deepen gradually from four to forty fathoms, within a distance of six or seven miles, over which the discoloured fresh water extends; so that the inclination of the new deposits must be too slight to be appreciable in such an extent of section as a geologist usually obtains in examining ancient formations. When the wind blew from the south-west, the ships employed in the survey were obliged to quit their moorings; and when they returned, the new sand-banks in the delta were found covered over with a great abundance of marine shells. By this means, we learn how occasional beds of drifted marine shells may become interstratified with fresh-water strata at the mouths of rivers.

Stony nature of its deposits.—That a great proportion, at least, of the new deposit in the delta of the Rhone consists of *rock*, and not of loose incoherent matter, is perfectly ascertained. In the Museum at Montpellier is a cannon taken up from the sea near the mouth of the river, imbedded in a crystalline calcareous rock. Large masses, also, are continually taken up of an arenaceous rock, cemented by calcareous matter, including multitudes of broken shells of recent species. The observations recently made on this subject corroborate the former statement of Marsilli*, that the earthy deposits of the

* Hist. Phys. de la Mer.

coast of Languedoc form a stony substance, for which reason he ascribed a certain bituminous, saline, and glutinous nature to the substances brought down with sand by the Rhone. If the number of mineral springs charged with carbonate of lime which fall into the Rhone and its feeders in different parts of France be considered, we shall feel no surprise at the lapidification of the newly-deposited sediment in this delta. It should be remembered that the fresh water introduced by rivers, being lighter than the water of the sea, floats over the latter, and remains upon the surface for a considerable distance. Consequently, it is exposed to as much evaporation as the waters of a lake; and the area over which the river-water is spread, at the junction of great rivers and the sea, may well be compared, in point of extent, to that of considerable lakes.

Now, it is well known, that so great is the quantity of water carried off by evaporation in some lakes, that it is nearly equal to the water flowing in; and in some inland seas, as the Caspian, it is quite equal. We may, therefore, well suppose that, in cases where a strong current does not interfere, the greater portion not only of the matter held mechanically in suspension, but of that also which is in chemical solution, must be precipitated within the limits of the delta. When these finer ingredients are extremely small in quantity, they may only suffice to supply crustaceous animals, corals, and marine plants, with the earthy particles necessary for their secretions; but whenever it is in excess (as generally happens if the basin of a river lie partly in a district of active or extinct volcanos), then will solid deposits be formed, and the shells will at once be included in a rocky mass.

Delta of the Po.—The Adriatic presents a great combination of circumstances favourable to the rapid formation of deltas—a gulf receding far into the land,—a sea without tides or strong currents, and the influx of two great rivers, the Po and the Adige, besides numerous minor streams draining on the one side a great crescent of the Alps, and on the other

some of the loftiest ridges of the Apennines. From the northernmost point of the Gulf of Trieste, where the Isonzo enters, down to the south of Ravenna, there is an uninterrupted series of recent accessions of land, more than one hundred miles in length, which, within the last two thousand years, have increased from *two to twenty miles in breadth*. The Isonzo, Tagliamento, Piave, Brenta, Adige, and Po, besides many other inferior rivers, contribute to the advance of the coast-line, and to the shallowing of the gulf. The Po and the Adige may now be considered as entering by one common delta, for two branches of the Adige are connected with arms of the Po.

In consequence of the great concentration of the flooded waters of these streams, since the system of embankment became general, the rate of encroachment of the new land upon the Adriatic, especially at that point where the Po and Adige enter, is said to have been greatly accelerated. Adria was a seaport in the time of Augustus, and had, in ancient times, given its name to the gulf; it is now about twenty Italian miles inland. Ravenna was also a seaport, and is now about four Italian miles from the main sea. Yet even before the practice of embankment was introduced, the alluvium of the Po advanced with rapidity on the Adriatic; for Spina, a very ancient city, originally built in the district of Ravenna, at the mouth of a great arm of the Po, was, so early as the commencement of our era, eleven Italian miles distant from the sea *.

The greatest depth of the Adriatic, between Dalmatia and the mouths of the Po, is twenty-two fathoms; but a large part of the gulf of Trieste and the Adriatic, opposite Venice, is less than twelve fathoms deep. Farther to the south, where it is less affected by the influx of great rivers, the gulf deepens considerably. Donati, after dredging the bottom, discovered the new deposits to consist partly of mud and partly of rock,

* See Brocchi on the various writers on this subject. Conch. Foss. Subap., vol. i. p. 118.

the latter formed of calcareous matter, encrusting shells. He also ascertained, that particular species of testacea were grouped together in certain places, and were becoming slowly incorporated with the mud, or calcareous precipitates *. Olivi, also, found some deposits of sand, and others of mud, extending half way across the gulf; and he states that their distribution along the bottom was evidently determined by the prevailing current †. It is probable, therefore, that the finer sediment of all the rivers at the head of the Adriatic may be intermingled by the influence of the current; and all the central parts of the gulf may be considered as slowly filling up with horizontal deposits, precisely similar to those of the Subapennine hills, and containing many of the same species of shells. The Po merely introduces at present fine sand and mud, for it carries no pebbles farther than the spot where it joins the Trebia, west of Piacenza. Near the northern borders of the basin, the Isonzo, Tagliamento, and many other streams, are forming immense beds of sand and some conglomerate, for there some high mountains of Alpine limestone approach within a few miles of the sea.

In the time of the Romans, the hot-baths of Monfalcone were on one of several islands of Alpine limestone, between which and the main land, on the north, was a channel of the sea, about a mile broad. This channel is now converted into a grassy plain, which surrounds the islands on all sides. Among the numerous changes on this coast, we find that the present channel of the Isonzo is several miles to the west of its ancient bed, in part of which, at Ronchi, the old Roman bridge which crossed the Via Appia was lately found buried in fluviatile silt.

Notwithstanding the present shallowness of the Adriatic, it is highly probable that its original depth was very great; for if all the low alluvial tracts were taken away from its borders and replaced by sea, the high land would terminate in that

* See Brocchi on the various writers on this subject.—Conch. Foss. Subap., vol. i. p. 39. † Ibid., vol. ii. p. 94.

abrupt manner which generally indicates, in the Mediterranean, a great depth of water near the shore, except in those spots where sediment imported by rivers and currents has diminished the depth. Many parts of the Mediterranean are now ascertained to be above two thousand feet deep, close to the shore, as between Nice and Genoa; and even sometimes six thousand feet, as near Gibraltar. When, therefore, we find near Parma, and in other districts in the interior of the peninsula, beds of horizontal tertiary marl, attaining a thickness of about two thousand feet, or when we discover strata of inclined conglomerate, of the same age, near Nice, measuring above a thousand feet in thickness, and extending seven or eight miles in length, we behold nothing which the analogy of the deltas in the Adriatic might not lead us to anticipate.

Delta of the Nile.—That Egypt was the gift of the Nile, was the opinion of her priests before the time of Herodotus; but we have no authentic memorials for determining, with accuracy, the additions made to the habitable surface of that country since the earliest historical period. We know that the base of the delta has been considerably modified since the days of Homer. The ancient geographers mention seven principal mouths of the Nile, of which the most eastern, the Pelusian, has been entirely silted up, and the Mendesian, or Tanitic, has disappeared. On the other hand, the Bucolic has, in modern times, been greatly enlarged, and has caused the coast to advance; so that the city of Damietta, which, in the year 1243, was on the sea, and possessed a good harbour, is now one mile inland. The Phatnitic mouth, and the Sebenitic, have been so altered, that the country immediately about them has little resemblance to that described by the ancients. The Bolbitine mouth has increased in its dimensions, so as to cause the city of Rosetta to be at some distance from the sea.

But the alterations produced round the Canopic mouth are the most important. The city Foah, which, so late as the beginning of the fifteenth century, was on this embouchure, is now more than a mile inland. Canopus, which, in the time of

Scylax, was a desolate insular rock, has been connected with the firm land; and Pharos, an island in the times of old, now belongs to the continent. Homer says, its distance from Egypt was one day's voyage by sea *. That this should have been the case in Homer's time, Larcher and others have, with reason, affirmed to be in the highest degree improbable; but Strabo has judiciously anticipated their objections, observing, that Homer was probably acquainted with the gradual advance of the land on this coast, and availed himself of this phenomenon to give an air of higher antiquity to the remote period in which he laid the scene of his poem †. The Lake Mareotis, also, together with the canal which connected it with the Canopic arm of the Nile, has been filled with mud, and is become dry. Herodotus observes, that the country round Memphis seemed formerly to have been an arm of the sea gradually filled by the Nile, in the same manner as the Meander, Achelous, and other streams, had formed deltas. 'Egypt, therefore,' he says, 'like the Red Sea, was once a long narrow bay, and both gulfs were separated by a small neck of land. If the Nile,' he adds, 'should by any means have an issue into the Arabian Gulf, it might choke it up with earth in twenty thousand, or even, perhaps, in ten thousand years; and why may not the Nile have filled with mud a still greater gulf, in the space of time which has passed before our age ‡?'

Mud of the Nile.—The analysis of the mud of the Nile gives nearly one-half of argillaceous earth, and about one-fourth of carbonate of lime, the remainder consisting of water, oxide of iron, and carbonate of magnesia §.

The depth of the Mediterranean is about twelve fathoms at a small distance from the shore of the delta; it afterwards increases gradually to fifty, and then suddenly descends to three hundred and eighty fathoms, which is, perhaps, the original

* Ody., book iv. p. 355.

† Lib. I., Part i. pp. 80 and 98. Consult Von Hoff, vol. i. p. 244.

‡ Euterpe, XI.

§ Girard, Mém. sur l'Egypte, tome i. pp. 348, 382.

depth of the sea where it has not been rendered shallower by fluviatile matter. The progress of the delta, in the last two thousand years, affords, perhaps, no measure for estimating its rate of growth when it was an inland bay, and had not yet protruded itself beyond the coast-line of the Mediterranean. A powerful current now sweeps along the shores of Africa, from the Straits of Gibraltar to the prominent convexity of Egypt, the western side of which is continually the prey of the waves; so that not only are fresh accessions of land checked, but ancient parts of the delta are carried away. By this cause Canopus, and some other towns, have been overwhelmed; but to this subject we shall again refer when speaking of tides and currents.

CHAPTER XIV.

Oceanic deltas—Delta of the Ganges and Burrampooter—Its size, rate of advance, and nature of its deposits—Formation and destruction of islands—Abundance of crocodiles—Inundations—Delta of the Mississippi—Deposits of drift wood—Gradual filling up of the Yellow Sea—Rennell's estimate of the mud carried down by the Ganges—Formation of valleys illustrated by the growth of deltas—Grouping of new strata in general—Convergence of deltas—Conglomerates—Various causes of stratification—Direction of laminæ—Remarks on the interchange of land and sea.

OCEANIC DELTAS.

The remaining class of deltas are those in which rivers, on entering the sea, are exposed to the influence of the tides. In this case it frequently happens that an estuary is produced, or negative delta, as it has been termed by Rennell, where, instead of any encroachment of the land upon the sea, the ocean enters the river's mouth, and penetrates into the land beyond the general coast-line. Where this happens, the tides and currents are the predominating agents in the distribution of transported sediment. The phenomena, therefore, of such estuaries, will come under our examination when we treat of the movements of the ocean. But whenever the volume of fresh water is so great as to counteract and almost neutralize the force of tides and currents, and in all cases where the latter agents have not sufficient power to remove to a distance the whole of the sediment periodically brought down by rivers, oceanic deltas are produced. Of these, we shall now select a few illustrative examples.

Delta of the Ganges.—The Ganges and the Burrampooter descend, from the highest mountains in the world, into a gulf which runs two hundred and twenty-five miles into the continent. The Burrampooter is somewhat the larger river of the two, but it first takes the name of the Megna, when joined by a

smaller stream so called, and afterwards loses this second name also on its union with the Ganges, at the distance of about forty miles from the sea. The area of the delta of the Ganges (without including that of the Burrampooter, which has now become conterminous) is considerably more than double that of the Nile; and its head commences at a distance of two hundred and twenty miles, in a direct line from the sea. That part of the delta bordering on the sea is composed of a labyrinth of rivers and creeks, all of which are salt, except those immediately communicating with the principal arm of the Ganges. This tract, known by the name of the Woods, or Sunderbunds, a wilderness infested by tigers and alligators, is, according to Rennell, equal in extent to the whole principality of Wales *. The base of this magnificent delta is two hundred miles in length, including the space occupied by the two great arms of the Ganges which bound it on either side.

On the sea-coast there are eight great openings, each of which has evidently, at some ancient period, served in its turn as the principal channel of discharge. Although the flux and reflux of the tide extend even to the head of the delta, when the river is low, yet, when it is periodically swollen by tropical rains, the velocity of the stream counteracts the tidal current, so that, except very near the sea, the ebb and flow become insensible. During the flood season, therefore, the Ganges almost assumes the character of a river entering a lake or inland sea; the movements of the ocean being then subordinate to the force of the river, and only slightly disturbing its operations. The great gain of the delta in height and area takes place during the inundations; and during other seasons of the year, the ocean makes reprisals, scouring out the channels, and sometimes devouring rich alluvial plains.

So great is the quantity of mud and sand poured by the Ganges into the gulf in the flood-season, that the sea only recovers its transparency at the distance of sixty miles from the

* Account of the Ganges and Burrampooter Rivers, by Major Rennell, Phil. Trans. 1781.

coast. The general slope, therefore, of the new strata must be extremely gradual. By the charts recently published, it appears that there is a gradual deepening from four to about sixty fathoms, as we proceed from the base of the delta to the distance of about one hundred miles into the Bay of Bengal. At some few points seventy, or even one hundred fathoms are obtained at that distance.

One remarkable exception, however, occurs to the regularity of the shape of the bottom; for opposite the middle of the delta, at the distance of thirty or forty miles from the coast, is a nearly circular space called the 'swatch of no ground,' about fifteen miles in diameter, where soundings of one hundred, and even one hundred and thirty fathoms, fail to reach the bottom. This phenomenon is the more extraordinary, since the depression occurs within five miles of the line of shoals; and not only do the waters charged with Gangetic sediment pass over it continually, but, during the monsoons, the sea, loaded with mud and sand, is beaten back in that direction towards the delta. As the mud is known to extend for eighty miles farther into the gulf, we may be assured that, in the course of ages, the accumulation of strata in 'the swatch' has been of enormous thickness; and we seem entitled to deduce, from the present depth at the spot, that the original inequalities of the bottom of the Bay of Bengal were on as grand a scale as are those of the main ocean.

Opposite the mouth of the Hoogly river, and immediately south of Sager Island, four miles from the nearest land of the delta, a new isle was formed about thirty years ago, called Edmonston Island, where there is a lighthouse, and the surface of which is now covered with vegetation and shrubs. But while there is evidence of rapid gain at some points, the general progress of the coast is very slow, for the tides, which rise from thirteen to sixteen feet, are actively employed in removing the alluvial matter, and diffusing it over a wide area *. The new

* It is stated in the chart published in the year 1825, by Captain Horsburgh, that the sands opposite the whole delta stretched between four and five miles

strata consist entirely of sand and fine mud; such, at least, are the only materials which are exposed to view in regular beds on the banks of the numerous creeks. No substance so coarse as gravel occurs in any part of the delta, nor nearer the sea than four hundred miles. It should be observed, however, that the superficial alluvial beds, which are thrown down rapidly from turbid waters during the floods, may be very distinct from those deposited at a greater distance from the shore, where crystalline precipitates, perhaps, are forming, on the evaporation of so great a surface, exposed to the rays of a tropical sun. The separation of sand and other matter, held in mechanical suspension, may take place where the waters are in motion; but mineral ingredients, held in chemical solution, would naturally be carried to a greater distance, where they aid in the formation of corals and shells, and, in part, perhaps, become the cementing principle of rocky masses.

A well was sunk at Fort William, Calcuttta, in the hope of obtaining water through beds of adhesive clay to the depth of one hundred and forty-six feet. A bed of yellow sand was then entered, and at the depth of one hundred and fifty-two feet another stratum of clay*.

Islands formed and destroyed.—The immense transportation of earthy matter by the Ganges and Megna, is proved by the great magnitude of the islands formed in their channels during a period far short of that of a man's life. Some of these, many miles in extent, have originated in large sand-banks thrown up round the points at the angular turning of the river, and afterwards insulated by breaches of the stream. Others, formed in the main channel, are caused by some obstruction at the bottom. A large tree, or a sunken boat, is sometimes

farther south than they had done forty years previously; and this was taken as the measure of the progress of the delta itself, during the same period. But that gentleman informs me that a more careful comparison of the ancient charts, during a recent survey, has proved that they were extremely incorrect in their latitudes, so that the advance of the new sands and delta was greatly exaggerated.

* See India Gazette, June 9, 1831.

sufficient to check the current, and cause a deposit of sand, which accumulates till it usurps a considerable portion of the channel. The river then borrows on each side to supply the deficiency in its bed, and the island is afterwards raised by fresh deposits during every flood. In the great gulf below Luckipour, formed by the united waters of the Ganges and Burrampooter (or Megna), some of the islands, says Rennell, rival in size and fertility the Isle of Wight. While the river is forming new islands in one part, it is sweeping away old ones in others. Those newly formed are soon overrun with reeds, long grass, the Tamarix Indica, and other shrubs, forming impenetrable thickets, where tigers, buffaloes, deer, and other wild animals, take shelter. It is easy, therefore, to perceive, that both animal and vegetable remains must continually be precipitated into the flood, and sometimes become imbedded in the sediment which subsides in the delta.

Two species of crocodiles, of distinct genera, abound in the Ganges and its tributary and contiguous waters; and Mr. H. T. Colebrooke informs me, that he has seen both kinds in places far inland, many hundred miles from the sea. The Gangetic crocodile, or Gavial (in correct orthography, Garial), is confined to the fresh-water, but the common crocodile frequents both fresh and salt; being much larger and fiercer in salt and brackish water. These animals swarm in the brackish water along the line of sand-banks where the advance of the delta is most rapid. Hundreds of them are seen together in the creeks of the delta, or basking in the sun on the shoals without. They will attack men and cattle, destroying the natives when bathing, and tame and wild animals which come to drink. 'I have not unfrequently,' says Mr. Colebrooke, 'been witness to the horrid spectacle of seeing a floating corpse seized by a crocodile with such avidity, that he half emerged above the water with his prey in his mouth.' The geologist will not fail to observe how peculiarly the habits and distribution of these saurians expose them to become imbedded in those horizontal strata of fine mud which are annually de-

posited over many hundred square miles in the Bay of Bengal. The inhabitants of the land, when they happen to be submerged, are usually destroyed by these voracious reptiles; but we may suppose the remains of the saurians themselves to be continually entombed in the new formations.

Inundations.—It sometimes happens, at the season when the periodical flood is at its height, that a strong gale of wind, conspiring with a high spring-tide, checks the descending current of the river, and gives rise to most destructive inundations. From this cause, in the year 1763, the waters at Luckipour rose six feet above their ordinary level, and the inhabitants of a considerable district, with their houses and cattle, were totally swept away.

The population of all oceanic deltas are particularly exposed to suffer by such catastrophes recurring at considerable intervals of time; and we may safely assume, that such tragical events have happened again and again since the Gangetic delta was inhabited by man. If human experience and forethought cannot always guard against these calamities, still less can the inferior animals avoid them; and the monuments of such disastrous inundations must be looked for in great abundance in strata of all ages, if the surface of our planet has always been governed by the same laws. When we reflect on the general order and tranquillity that reigns in the rich and populous delta of Bengal, notwithstanding the havoc occasionally committed by the depredations of the ocean, we perceive how unnecessary it is to attribute the imbedding of successive races of animals in older strata to extraordinary energy in the causes of decay and reproduction in the infancy of our planet, or to those general catastrophes and sudden revolutions resorted to by cosmogonists.

Delta of the Mississippi.—As the delta of the Ganges may be considered a type of those formed on the borders of the ocean, it will be unnecessary to accumulate examples of others on a no less magnificent scale, as at the mouths of the Orinoco and Amazon, for example. To these, indeed, it will be neces-

sary to revert when we treat of the agency of currents. The tides in the Mexican Gulf are so feeble, that the delta of the Mississippi has somewhat of an intermediate character between an oceanic and mediterranean delta. A long narrow tongue of land is protruded, consisting simply of the banks of the river, and having precisely the same appearance as in the inland plains during the periodical inundations, when nothing appears above water but the higher part of that sloping glacis which we before described. This tongue of land has advanced many leagues since New Orleans was built. Great submarine deposits are also in progress, stretching far and wide over the bottom of the sea, which has become throughout a considerable area, extremely shallow, not exceeding ten fathoms in depth. Opposite the mouth of the Mississippi large rafts of drift trees, brought down every spring, are matted together into a network many yards in thickness, and stretching over hundreds of square leagues*. They afterwards become covered over with a fine mud, on which other layers of trees are deposited the year following, until numerous alternations of earthy and vegetable matter are accumulated.

Alternation of Deposits.—An observation of Darby, in regard to the strata composing part of this delta, deserves attention. In the steep banks of the Atchafalaya, that arm of the Mississippi which we before alluded to when describing 'the raft,' the following section is observable at low water:—first, an upper stratum, consisting invariably of blueish clay, common to the banks of the Mississippi; below this a stratum of red ochreous earth peculiar to Red River, under which the blue clay of the Mississippi again appears †; and this arrangement is constant, proving, as that geographer remarks, that the waters of the Mississippi and the Red River once occupied alternately considerable tracts below their present point of union. Such alternations are probably common in submarine spaces situated between two converging deltas. For, before the

* Captain Hall's Travels in North America, vol. iii. p. 338.

† Darby's Louisiana, p. 103.

two rivers unite, there must almost always be a certain period when an intermediate tract will be alternately occupied and abandoned by the waters of each stream; since it can rarely happen that the season of highest flood will precisely correspond in each. In the case of the Red River, for example, and Mississippi, which carry off the waters from countries placed under widely distant latitudes, an exact coincidence in the time of greatest inundation is very improbable.

CONCLUDING REMARKS ON DELTAS.

Quantity of sediment in river water.—Very few satisfactory experiments have as yet been made, to enable us to determine, with any degree of accuracy, the mean quantity of earthy matter discharged annually into the sea by some one of the principal rivers of the earth. Hartsoeker computed the Rhine to contain in suspension, when most flooded, one part in a hundred of mud in volume *. By several observations of Sir George Staunton, it appeared that the water of the Yellow River in China contained earthy matter in the proportion of one part to two hundred, and he calculated that it brought down in a single hour two million cubic feet of earth, or forty-eight million daily; so that, if the Yellow Sea be taken to be one hundred and twenty feet deep, it would require seventy days for the river to convert an English square mile into firm land, and twenty-four thousand years to turn the whole sea into terra firma, assuming it to be one hundred and twenty-five thousand square miles in area †. Manfredi, the celebrated Italian hydrographer, conceived the average proportion of sediment in all the running water on the globe, which reached the sea, to be $\frac{1}{175}$, and he imagined that it would require a thousand years for the sediment carried down to raise the general level of the sea about one foot. Some writers, on the contrary, as De Maillet, have declared the most turbid waters to contain far less sediment than any of the above estimates would im-

* Comment. Bonon., vol. ii. part i. p. 237.

† Staunton's Embassy to China, London, 1797, 4to, vol. ii. p. 408.

port; and there is so much contradiction and inconsistency in the facts and speculations hitherto promulgated on the subject, that we must wait for additional experiments before we can form any opinion on the question.

Rennell's estimate of the mud carried down by the Ganges.— One of the most extraordinary statements is that of Major Rennell, in his excellent paper, before referred to, on the Delta of the Ganges. 'A glass of water,' he says, 'taken out of this river when at its height, yields about one part in four of mud. No wonder then that the subsiding waters should quickly form a stratum of earth, or that the delta should encroach on the sea *!' The same hydrographer computed with much care the number of cubic feet of water discharged by the Ganges into the sea, and estimated the mean quantity through the whole year to be 180,000 cubic feet in a second. When the river is most swollen, and its velocity much accelerated, the quantity is 405,000 cubic feet in a second. Other writers agree that the violence of the tropical rains, and the fineness of the alluvial particles in the plains of Bengal, cause the waters of the Ganges to be charged with foreign matter to an extent wholly unequalled by any large European river during the greatest floods.

We have already alluded to the frequent sweeping down of large islands by the Ganges; and Major R. H. Colebrooke, in his account of the course of the Ganges, relates examples of the rapid filling up of some branches of the river, and the excavation of new channels, where the number of square miles of soil removed in a short time (the column of earth being one hundred and fourteen feet high) was truly astonishing. Forty square miles, or 25,600 acres, are mentioned as having been carried away, in one locality, in the course of a few years †. But, although we can readily believe the proportion of sediment in the waters of the Ganges to exceed that of any river in northern latitudes, we are somewhat staggered by the results to

* Phil. Trans., 1781.

† Trans. of the Asiatic Society, vol. vii. p. 14.

which we must arrive if we compare the proportion of mud, as given by Rennell, with his computation of the quantity of water discharged, which latter is probably very correct. If it were true that the Ganges, in the flood-season, contained one part in four of mud, we should then be obliged to suppose that there passes down, every four days, a quantity of mud equal in volume to the water which is discharged in the course of twenty-four hours. If the mud be assumed to be equal to one-half the specific gravity of granite (it would, however, be more), the weight of matter *daily* carried down in the flood-season would be about equal to seventy-four times the weight of the Great Pyramid of Egypt *. Even if it could be proved that the turbid waters of the Ganges contain one part *in a hundred* of mud, which is possible, and which is affirmed to be the case in regard to the Rhine, we should be brought to the extraordinary conclusion, that there passes down every day into the Bay of Bengal a mass more than equal in weight and bulk to the Great Pyramid.

The most voluminous current of lava which has flowed from Etna within historical times was that of 1669. Ferrara, after correcting Borrelli's estimate, calculated the quantity of cubic yards of lava in this current at one hundred and forty millions. Now, this would not equal in bulk one-fifteenth of the sedimentary matter which is carried down in a single year by the Ganges, assuming the average proportion of mud to water to be one part in one hundred, so that, allowing fifteen grand eruptions in a century, it would require an hundred Etnas to transfer a mass of lava from the subterranean regions to the

* According to Rennell, the Ganges discharges, in the flood-season, 405,000 cubic feet of water per second, which gives in round numbers 100,000 cubic feet of mud per second, which × 86,400, the number of seconds in twenty-four hours, = 8,640,000,000, the quantity of cubic feet of mud going down the Ganges per diem. Assuming the specific gravity of mud to be half that of granite, the matter would equal 4,320,000,000 feet of granite. Now, about twelve and a half cubic feet of granite weigh one ton; and it is computed that the Great Pyramid of Egypt, if it were a solid mass of granite, would weigh about 6,000,000 of tons.

surface equal in volume to the mud carried down in the same time from the Himalaya mountains into the Bay of Bengal *.

As considerable labour has been bestowed in computing the volume of lava-streams in Sicily, Campania, and Auvergne, it is somewhat extraordinary that so few observations have been made on the quantity of matter transported by aqueous agents from one part of the earth to another. It would certainly not be difficult to approximate to the amount of sediment carried down annually by some of the largest rivers, such as the Amazon, Mississippi, Ganges, and others, because the earthy particles conveyed by them to their deltas are fine, and somewhat uniformly spread throughout the stream, and the principal efflux takes place within a limited period during the season of inundation. Arguments have been expended in vain for half a century in controverting the opinion of those who imagine the agency of running water in the existing state of things, even if continued through an indefinite lapse of ages, to be insignificant, or at least wholly incompetent to produce considerable inequalities on the earth's surface. Some matter-of-fact data should now be accumulated, and we may confidently affirm that, when the aggregate amount of solid matter transported by rivers in a given number of centuries from a large continent shall be reduced to arithmetical computation, the result will appear most astonishing to those who are not in the habit of reflecting how many of the mightiest operations in nature are effected insensibly, without noise or disorder. The volume of matter carried into the sea in a given time being once ascertained, every geologist will admit that the whole, with some slight exceptions, is subtracted from *valleys*, not from the tops of intervening ridges or the summits of hills; in other words,

† According to Ferrara's calculation, about 140,000,000 of cubic yards of lava were poured from the crater of Etna in 1669. This × 27, will give 3,780,000,000 of cubic feet, which would be about one-fifteenth of the amount of mud carried down by the Ganges in a year; for, assuming the average proportion of mud to be one part in a hundred, this would give on an average 1800 cubic feet per second: 1800 × 31,557,600 (the number of seconds in a Julian year), gives 56,803,680,000.

that ancient valleys have been widened and deepened, or new ones formed, to the extent of the space which the new deposits, when consolidated, would occupy.

Grouping of Strata in Deltas.—The changes which have taken place in deltas, even since the times of history, may suggest many important considerations in regard to the manner of distribution of sediment in subaqueous deposits. Notwithstanding frequent exceptions arising from the interference of a variety of causes, there are some general laws of arrangement which must evidently hold good in almost all the lakes and seas now filling up. If a lake, for example, be encircled on two sides by lofty mountains, receiving from them many rivers and torrents of different sizes, and if it be bounded on the other sides, where the surplus waters issue, by a comparatively low country, it is not difficult to define some of the leading geological features which will characterize the lacustrine formation when this basin shall have been gradually converted into dry land by influx of fluviatile sediment. The strata would be divisible into two principal groups: the *older* comprising those deposits which originated on the side adjoining the mountains, where numerous deltas first began to form; and the *newer* group consisting of beds deposited in the more central parts of the basin, and towards the side farthest from the mountains. The following characters would form the principal marks of distinction between the strata in each series. The more ancient system would be composed, for the most part, of coarser materials, containing many beds of pebbles and sand often of great thickness, and sometimes dipping at a considerable angle. These, with associated beds of finer ingredients, would, if traced round the borders of the basin, be seen to vary greatly in colour and mineral composition, and would also be very irregular in thickness. The beds, on the contrary, in the newer group, would consist of finer particles, and would be horizontal, or very slightly inclined. Their colour and mineral composition would be very homogeneous throughout large areas, and would differ from almost all the separate beds in the older series.

The following are the causes of the diversity here alluded to between the two great members of the lacustrine formation. When the rivers and torrents first reach the edge of the lake, the detritus washed down by them from the adjoining heights sinks at once into deep water, all the heavier pebbles and sand subsiding near the shore. The finer mud is carried somewhat farther out, but not to the distance of many miles, for the greater part may be seen, where the Rhone enters the Lake of Geneva, to fall down in clouds to the bottom not far from the river's mouth. Certain alluvial tracts are soon formed at the mouths of every torrent and river, and many of these, in the course of ages, become several miles in length. Pebbles and sand are then transported farther from the mountains, but in their passage they decrease in size by attrition, and are in part converted into mud and sand. At length some of the numerous deltas, which are all directed towards a common centre, approach near to each other—those of adjoining torrents become united, and are merged, in their turn, in the delta of the largest river, which advances most rapidly into the lake, and renders all the minor streams, one after the other, its tributaries. The various mineral ingredients of each are thus blended together into one homogeneous mixture, and the sediment is poured out from a common channel into the lake.

As the average size of the transported particles decreases continually, so also the force and volume of the current augments, and thus the newer deposits are diffused over a wider area, and are consequently more horizontal than the older. When there were many independent deltas near the borders of the basin, their separate deposits differed entirely from each other. We may suppose that one was charged, like the Arve where it joins the Rhone, with white sand and sediment, chiefly derived from decomposed granite—that another was black, like many streams in the Tyrol, flowing from incoherent rocks of dark slate—that a third was coloured by ochreous sediment, like the Red River in Louisiana—and that a fourth, like the Elsa in Tuscany, held much carbonate of lime in solution. At

first, they would each form distinct deposits of sand, gravel, limestone, marl, or other materials; but after their junction, new chemical combinations and distinct colours would be the result, and the particles, having been conveyed ten, twenty, or a greater number of miles over alluvial plains, would become finer.

In deltas where the causes are more complicated, and where tides and currents partially interfere, the above description would only be applicable, with certain modifications; but if a series of earthquakes accompany the growth of a delta, and change the levels of the land from time to time, as in the region where the Indus now enters the sea, and others hereafter to be mentioned, the phenomena will then depart widely from the ordinary type.

Convergence of Deltas.—If we possessed an accurate series of maps of the Adriatic for many thousand years, our retrospect would, without doubt, carry us gradually back to the time when the number of rivers descending from the mountains into that gulf by independent deltas, was far greater in number. The deltas of the Po and the Adige, for instance, would separate themselves within the *human* era, as, in all probability, would those of the Isonzo and the Torre. If, on the other hand, we speculate on future changes, we may anticipate the period when the number of deltas will greatly diminish; for the Po cannot continue to encroach at the rate of a mile in a century, and other rivers to gain as much in six or seven centuries upon the shallow gulf, without new junctions occurring from time to time, so that Eridanus, 'the king of rivers,' will continually boast a greater number of tributaries. The Ganges and Burrampooter have probably become confluent within the historical era; and the date of the junction of the Red River and the Mississippi would, in all likelihood, have been known, if America had not been so recently discovered. The union of the Tigris and the Euphrates must undoubtedly have been one of the modern geographical changes on our earth, and similar remarks might be extended to many other regions.

Formation of Conglomerates.—Along the base of the Maritime Alps, between Toulon and Genoa, the rivers, with few exceptions, are now forming strata of conglomerate and sand. Their channels are often several miles in breadth, some of them being dry, and the rest easily forded for nearly eight months in the year; whereas during the melting of the snow they are swollen, and a great transportation of mud and pebbles takes place. In order to keep open the main road from France to Italy, now carried along the sea-coast, it is necessary to remove annually great masses of shingle, brought down during the flood-season. A portion of the pebbles are seen in some localities, as near Nice, to form beds of shingle along the shore, but the greater part are swept into a deep sea. The small progress made by the deltas of minor rivers on this coast need not surprise us, when we recollect that there is sometimes a depth of two thousand feet at a few hundred yards from the beach, as near Nice. Similar observations might be made respecting a large proportion of the rivers in Sicily, and, among others, respecting that which, immediately north of the port of Messina, hurries annually vast masses of granitic pebbles into the sea.

When the deltas of rivers having many mouths converge, a partial union at first takes place by the confluence of some one or more of their arms; but it is not until the main trunks are connected above the head of the common delta, that a complete intermixture of their joint waters and sediment takes place. The union, therefore, of the Po and Adige, and of the Ganges and Burrampooter, is still incomplete. If we reflect on the geographical extent of surface drained by rivers such as now enter the bay of Bengal, and then consider how complete the blending together of the greater part of their transported matter has already become, and throughout how vast a delta it is spread by numerous arms, we no longer feel so much surprise at the area occupied by some ancient formations of homogeneous mineral composition. But our surprise will be still further lessened when we afterwards inquire into the action of tides

and currents, in disseminating the matter accumulated in various deltas.

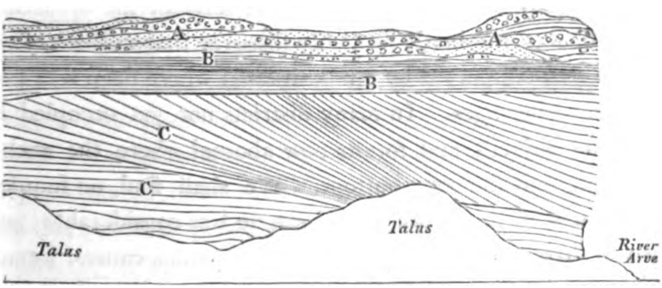
Stratification of Deposits in Deltas.—That the matter carried by rivers into seas and lakes is not thrown in confused and promiscuous heaps, but is spread out far and wide along the bottom, is well ascertained; and that it must for the most part be divided into distinct strata, may in part be inferred where it cannot be proved by observation. The horizontal arrangement of the strata, when laid open to the depth of twenty or thirty feet in the delta of the Ganges and in that of the Mississippi, is alluded to by many writers; and the same disposition is well known to obtain in all modern deposits of lakes and estuaries.

Natural divisions are often occasioned by the interval of time which separates annually the deposition of matter during the periodical rains, or melting of the snow upon the mountains. The deposit of each year acquires some degree of consistency before that of the succeeding year is superimposed. A variety of circumstances also give rise annually to slight variations in colour, fineness of the particles, and other characters. Alternations of strata distinct in texture, mineral ingredients, or organic contents, are produced by numerous causes. Thus, for example, at one period of the year, drift wood may be carried down, and at another mud, as was before stated to be the case in the delta of the Mississippi; or at one time when the volume and velocity of the stream are greatest, pebbles and sand may be spread over a certain area, over which, when the waters are low, fine matter or chemical precipitates are formed. During inundations the current of fresh water often repels the sea for many miles; but when the river is low, salt water again occupies the same space. When two deltas are converging, the intermediate space is often, for reasons before explained, alternately the receptacle of different sediments derived from the converging streams. The one is, perhaps, charged with calcareous, the other with argillaceous matter; or one may sweep down sand and pebbles, the other impal-

pable mud. These differences may be repeated, with considerable regularity, until a thickness of hundreds of feet of alternating beds is accumulated.

An examination of the strata of shell-marl now forming in the Scotch lakes, or of the sediment termed 'warp,' which subsides from the muddy water of the Humber, and other rivers, shows that recent deposits are often composed of a great number of extremely thin layers, either even or slightly undulating, and parallel to the planes of stratification. Sometimes, however, the laminæ in modern strata are disposed diagonally at a considerable angle, which appears to take place where there are conflicting movements in the waters. In January, 1829, I visited, in company with Professor L. A. Necker, of Geneva, the confluence of the Rhone and Arve, when those rivers were very low, and were cutting channels through the vast heaps of debris thrown down from the waters of the Arve, in the preceding spring. One of the sand-banks which had formed, in the spring of 1828, where the opposing currents of the two rivers neutralized each other, and caused a retardation in the motion, had been undermined; and the following is an exact representation of the arrangement of laminæ exposed in a vertical section. The length of the portion here seen is

No. 6.



Section on the banks of the Arve at its confluence with the Rhone, showing the stratification of deposits where currents meet.

about twelve feet, and the height five. The strata A A consist of irregular alternations of pebbles and sand in undulating

beds: below these are seams of very fine sand, B B, some as thin as paper, others about a quarter of an inch thick. The strata C C are composed of layers of fine greenish-gray sand, as thin as paper. Some of the inclined beds will be seen to be thicker at their upper, others at their lower extremity, the inclination of some being very considerable. These layers must have accumulated one on the other by lateral apposition, probably when one of the rivers was very gradually increasing or diminishing in velocity, so that the point of greatest retardation caused by their conflicting currents shifted slowly, allowing the sediment to be thrown down in successive layers on a sloping bank. The same phenomenon is exhibited in older strata of all ages; and when we treat of them, we shall endeavour more fully to illustrate the origin of such a structure.

Constant interchange of Land and Sea.—We may now conclude our remarks on deltas, observing that, imperfect as is our information of the changes which they have undergone within the last three thousand years, they are sufficient to show how constant an interchange of sea and land is taking place on the face of our globe. In the Mediterranean alone, many flourishing inland towns, and a still greater number of ports, now stand where the sea rolled its waves since the era when civilized nations first grew up in Europe. If we could compare with equal accuracy the ancient and actual state of all the islands and continents, we should probably discover that millions of our race are now supported by lands situated where deep seas prevailed in earlier ages. In many districts not yet occupied by man, land animals and forests now abound where the anchor once sank into the oozy bottom. We shall find, on inquiry, that inroads of the ocean have been no less considerable; and when to these revolutions produced by aqueous causes, we add analogous changes wrought by igneous agency, we shall, perhaps, acknowledge the justice of the conclusion of a great philosopher of antiquity, when he declared that the whole land and sea on our globe periodically changed places *.

* See an account of the Aristotelian system, p. 17, *ante.*

CHAPTER XV.

Destroying and transporting effects of tides and currents—Shifting of their position—Differences in the rise of the tides—Velocity of currents—Causes of currents—Action of the sea on the British coast—Shetland Islands—Large blocks removed—Effects of lightning—Breach caused in a mass of porphyry—Isles reduced to clusters of rocks—Orkney Isles—East coast of Scotland—Stones thrown up on the Bell Rock—East coast of England—Waste of the cliffs of Holderness, Norfolk, and Suffolk—Silting up of estuaries—Origin of submarine forests—Yarmouth estuary—Submarine forests—Suffolk coast—Dunwich—Essex coast—Estuary of the Thames—Goodwin sands—Coast of Kent—Formation of Straits of Dover—South coast of England—Coast of Sussex—Coast of Hants—Coast of Dorset—Portland—Origin of the Cheisil Bank—Cornwall—Lionesse tradition—Coast of Brittany.

DESTROYING AND TRANSPORTING EFFECTS OF TIDES AND CURRENTS.

ALTHOUGH the movements of great bodies of water, termed tides and currents, are in general due to very distinct causes, we cannot consider their effects separately, for they produce, by their joint action, those changes which are subjects of geological inquiry. We may view these forces as we before considered rivers, first as employed in destroying portions of the solid crust of the earth, and removing them to other localities; secondly, as reproductive of new strata. Some of the principal currents which traverse large regions of the globe depend on permanent winds, and these on the rotation of the earth on its axis, and its position in regard to the sun:—they are causes, therefore, as constant as the tides themselves, and, like them, depend on no temporary or accidental circumstances, but on the laws which preside over the motions of the heavenly bodies.

Currents shift their position.—But although the sum of their influence in altering the surface of the earth may be very constant throughout successive epochs, yet the points where these operations are displayed in the fullest energy shift perpetually. The height to which the tides rise, and the violence

and velocity of currents, depend in a great measure on the actual configuration of the land, the contour of a long line of continental or insular coast, the depth and breadth of channels, the peculiar form of the bottom of seas—in a word, on a combination of circumstances which are made to vary continually by many igneous and aqueous causes, and among the rest, by tides and currents. Although these agents, therefore, of decay and reproduction, are local in reference to periods of short duration, such as those which history in general embraces, they are nevertheless universal, if we extend our views to a sufficient lapse of ages.

Differences in the Rise of the Tides.—The tides, as is well known, rise in certain channels, bays, and estuaries, to an elevation far above the average height of the same tides in more open parts of the coast, or on islands in the main ocean. In all lakes, and in most inland seas, the tides are not perceptible. In the Mediterranean, even, deep and extensive as is that sea, they are only sensible in certain localities, and they then rarely rise more than six inches above the mean level. In the Straits of Messina, however, there is an ebb and flow every six hours, to the amount of two feet, but this elevation is partly due to the peculiar set of the currents. In islands remote from the shore, the rise of the tides is slight, as at St. Helena, for example, where it rarely exceeds three feet *. In the estuary of the Severn, the rise at King-Road, near Bristol, is forty-two feet; and at Chepstow on the Wye, a small river which opens into the same estuary, above fifty feet, and sometimes sixty-nine and even seventy-two feet †. All the intermediate elevations may be found at different places on our coast. Thus, at Milford Haven the rise is thirty-six feet; at London, and the promontory of Beachy Head, eighteen feet; at the Needles, in the Isle of Wight, nine feet; at Weymouth, seven; at Lowestoff, about five; at Great Yarmouth, still less. A current

* Romme, Vents et Courans, vol. ii. p. 2. Rev. F. Fallows, Quart. Journ. of Sci., March, 1829.

† On the authority of Captain Beaufort, R.N.

which sets in on the French coast, to the west of Cape La Hague, becomes pent up by Guernsey, Jersey, and other islands, till the rise of the tide is from twenty to forty-five feet, which last height is attained at Jersey, and at St. Malo's, a sea-port of Brittany.

Velocity of Currents.—On our eastern coast the strongest currents seldom exceed four miles and a half an hour. The current which runs through the Race of Alderney, between the island of that name and the main land, has a velocity of above eight English miles an hour. Captain Hewett found that in the Pentland Firth the stream, in ordinary spring tides, runs ten miles and a half an hour, and about thirteen miles during violent storms. The greatest velocity of the current through the 'shoots,' or new passage, in the Bristol Channel, is fourteen miles an hour, and Captain King observed, in his recent survey of the Straits of Magellan, that the tide ran at the same rate through the 'First Narrows.'

Causes of Currents.—That movements of no inconsiderable magnitude should be impressed on an expansive ocean, by winds blowing for many months in one direction, may easily be conceived, when we observe the effects produced in our own seas by the temporary action of the same cause. It is well known that a strong south-west or north-west wind invariably raises the tides to an unusual height along the east coast of England and in the Channel; and that a north-west wind of any continuance causes the Baltic to rise two feet and upwards above its ordinary level. Smeaton ascertained by experiment that, in a canal four miles in length, the water was kept up four inches higher at one end than at the other, merely by the action of the wind along the canal; and Rennell informs us that a large piece of water, ten miles broad, and generally only three feet deep, has, by a strong wind, had its waters driven to one side, and sustained so as to become six feet deep, while the windward side was laid dry *. As water, therefore, he observes, when pent up so that it cannot escape, acquires a higher

* Rennell on the Channel-current.

level, so, in a place *where it can escape,* the same operation produces a current; and this current will extend to a greater or less distance, according to the force by which it is produced. The most extensive and best determined of all currents is the Gulf stream which sets westward in tropical regions; and, after doubling the Cape of Good Hope, where it runs nearly at the rate of two miles an hour, inclines considerably to the northward, along the western coast of Africa, then crosses the Atlantic, and, having accumulated in the Gulf of Mexico, passes out at the Straits of Bahama, with a velocity of four miles an hour, which is not reduced to two miles until the stream has proceeded to the distance of eighteen hundred miles in the direction of Newfoundland: near that island it meets with a current setting southward from Baffin's Bay, on the coast of Greenland, and is thereby deflected towards the east. One branch extends in that direction, while another runs towards the north; so that fruits, plants, and wood, the produce of America and the West Indies, are drifted to the shores of Ireland, the Hebrides, and even to Spitzbergen.

In describing the destroying effects of tides and currents, it will be necessary to enter into some detail, because we have not the advantage here, as in the case of the deltas of many rivers, of viewing the aggregate mass which has resulted from the continual transportation of matter, for many centuries, at certain points. We must infer the great amount of accumulation as a corollary from the proofs adduced of the removing force; and this it will not be difficult to show is, on the whole, greater than that of running water on the land.

Action of the Sea on the British Coasts.—If we follow the eastern and southern shores of the British islands, from our Ultima Thule in Shetland to the Land's End in Cornwall, we shall find evidence of a series of changes since the historical era, very illustrative of the kind and degree of force exerted by the agents now under consideration. In this survey we shall have an opportunity of tracing the power of the sea on islands, promontories, bays, and estuaries; on bold, lofty cliffs, as well

as on low shores; and on every description of rock and soil, from granite to blown sand. We shall afterwards explain, by reference to other regions, some phenomena of which our own coast furnishes no examples.

Shetland Islands.—The northernmost group of the British islands, the Shetland, are composed of a great variety of primary and trap rocks, including granite, gneiss, mica-slate, serpentine, greenstone, and many others, with some secondary rocks, chiefly sandstone and conglomerate. These isles are exposed continually to the uncontrolled violence of the Atlantic, for no land intervenes between their western shores and America. The prevalence, therefore, of strong westerly gales causes the waves to be sometimes driven with irresistible force upon the coast, while there is also a current setting from the north. The spray of the sea aids the decomposition of the rocks, and prepares them to be breached by the mechanical force of the waves. Steep cliffs are hollowed out into deep caves and lofty arches; and almost every promontory ends in a cluster of rocks, imitating the forms of columns, pinnacles, and obelisks.

Drifting of large masses of rock.—Modern observations show that the reduction of continuous tracts to such insular masses is a process in which Nature is still actively engaged. 'The Isle of Stenness,' says Dr. Hibbert, 'presents a scene of unequalled desolation. In stormy winters, huge blocks of stones are overturned, or are removed from their native beds, and hurried up a slight acclivity to a distance almost incredible. In the winter of 1802, a tabular-shaped mass, eight feet two inches by seven feet, and five feet one inch thick, was dislodged from its bed, and removed to a distance of from eighty to ninety feet. I measured the recent bed from which a block had been carried away the preceding winter (A.D. 1818), and found it to be seventeen feet and a half by seven feet, and the depth two feet eight inches. The removed mass had been borne to a distance of thirty feet, when it was shivered into thirteen or more lesser fragments, some of which were carried

still farther, from thirty to one hundred and twenty feet. A block, nine feet two inches by six feet and a half, and four feet thick, was hurried up the acclivity to a distance of one hundred and fifty feet *.'

At Northmavine, also, angular blocks of stone have been removed in a similar manner to considerable distances by the waves of the sea, some of which are represented in the annexed figure, No. 7 †.

No. 7.

Stony fragments drifted by the sea. Northmavine, Shetland.

Effects of Lightning.—In addition to numerous examples of masses detached and driven by the tides and currents from their place, some remarkable effects of lightning are recorded in these isles. At Funzie, in Fetlar, about the middle of the last century, a rock of mica-schist, one hundred and five feet long, ten feet broad, and in some places four feet thick, was in an instant torn by a flash of lightning from its bed, and broken into three large, and several lesser fragments. One of these, twenty-six feet long, ten feet broad and four feet thick, was simply turned over. The second, which was twenty-eight feet long, seventeen broad, and five feet in thickness, was hurled across a high point to the distance of fifty yards. Another broken mass, about forty feet long, was thrown still farther,

* Dr. Hibbert, Description of the Shetland Islands, p. 527. Edin., 1822.

† For this, and the three following representations of rocks in the Shetland Isles, I am indebted to Dr. Hibbert's work before cited, which is rich in antiquarian and geological research.

but in the same direction, quite into the sea. There were also many lesser fragments scattered up and down *.

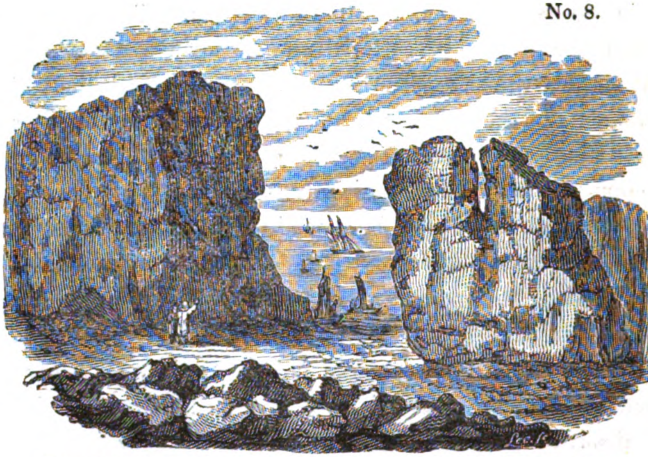
When we thus see electricity co-operating with the violent movements of the ocean in heaping up piles of shattered rocks on dry land, and beneath the waters, we cannot but admit that a region which shall be the theatre, for myriads of ages, of the action of such disturbing causes, will present, at some future period, a scene of havoc and ruin that may compare with any now found by the geologist on the surface of our continents, raised as they all have been in former ages from the bosom of the deep. We have scarcely begun, as yet, to study the effects of a single class of the mighty instruments of change and disorder now operating on our globe; and yet geologists have presumed to resort to a nascent order of things, or to revolutions in the economy of Nature, to explain every obscure phenomenon!

In some of the Shetland Isles, as on the west of Meikle Roe, dikes, or veins of soft granite, have mouldered away; while the matrix in which they were inclosed, being of the same substance, but of a firmer texture, has remained unaltered. Thus, long narrow ravines, sometimes twenty feet wide, are laid open, and often give access to the waves. After describing some huge cavernous apertures into which the sea flows for two hundred and fifty feet in Roeness, Dr. Hibbert enumerates other ravages of the ocean. 'A mass of rock, the average dimensions of which may perhaps be rated at twelve or thirteen feet square, and four and a half or five in thickness, was first moved from its bed, about fifty years ago, to a distance of thirty feet, and has since been twice turned over.'

Passage forced by the sea through porphyritic rocks.—'But the most sublime scene is where a mural pile of porphyry, escaping the process of disintegration that is devastating the coast, appears to have been left as a sort of rampart against the inroads of the ocean;—the Atlantic, when provoked by wintry gales, batters against it with all the force of real artillery—the

* Dr. Hibbert, from MSS. of Rev. George Low, of Fetlar.

No. 8.



Grind of the Navir—Passage forced by the sea through rocks of hard porphyry.

waves having, in their repeated assaults, forced themselves an entrance. This breach, named the Grind of the Navir (No. 8), is widened every winter by the overwhelming surge that, finding a passage through it, separates large stones from its sides, and forces them to a distance of no less than one hundred and eighty feet. In two or three spots, the fragments which have been detached, are brought together in immense heaps, that appear as an accumulation of cubical masses, the product of some quarry *.'

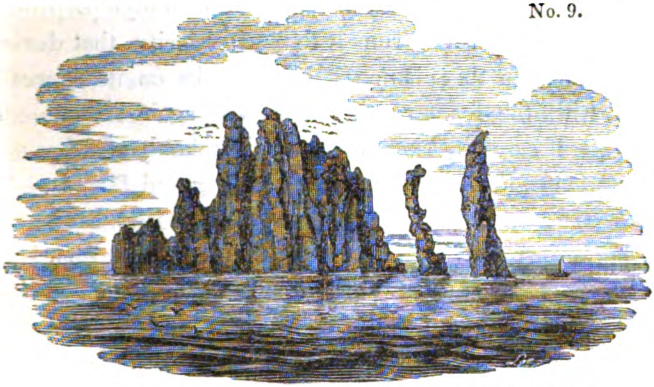
It is evident, from this example, that although the greater indestructibility of some rocks may enable them to withstand, for a longer time, the action of the elements, yet they cannot permanently resist. There are localities in Shetland, in which rocks of almost every variety of mineral composition are suffering disintegration: thus the sea makes great inroads on the clay slate of Fitfel Head, on the serpentine of the Vord Hill in Fetlar, and on the mica-schist of the Bay of Triesta, on the east coast of the same isle, which decomposes into angular blocks. The quartz rock on the east of Walls, and the gneiss and mica-schist of Garthness, suffer the same fate.

Destruction of islands.—Such devastation cannot be inces-

* Hibbert, p. 528.

santly committed for thousands of years without dividing islands, until they become at last mere clusters of rocks, the last shreds of masses once continuous. To this state many appear to have been reduced, and innumerable fantastic forms are assumed by rocks adjoining these isles, to which the name of Drongs is applied, as it is to those of similar shape in Feroe.

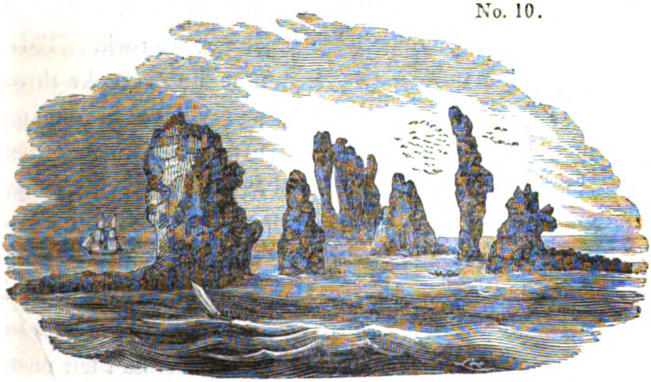
No. 9.



Granitic rocks named the Drongs, between Papa Stour and Hillswick Ness.

The granitic rocks (No. 9), between Papa Stour and Hillswick Ness afford an example. A still more singular cluster of rocks is seen to the south of Hillswick Ness (No. 10), which presents a variety of forms as viewed from different points, and has often been likened to a small fleet of vessels with spread sails *.

No. 10.



Granitic rocks to the south of Hillswick Ness, Shetland.

* Hibbert, p. 519.

We may imagine that in the course of time Hillswick Ness itself may present a similar wreck, from the unequal decomposition of the rocks whereof it is composed, consisting of gneiss and mica-schist, traversed in all directions by veins of felspar porphyry.

Midway between the groups of Shetland and Orkney is Fair Island, said to be composed of sandstone with high perpendicular cliffs. The current runs with such velocity, that during a calm, and when there is no swell, the rocks on its shores are white with the foam of the sea driven against them. The Orkneys, if carefully examined, would probably afford as much illustration of our present topic as the Shetland Islands. The north-east promontory of Sanda, one of these isles, has been cut off in modern times by the sea, so that it became what is now called Start Island, where a lighthouse was erected in 1807, since which time the new strait has grown broader.

East coast of Scotland.—To pass over to the main land of Scotland, we find that, in Inverness-shire, there have been inroads of the sea at Fort George, and others in Murrayshire, which have swept away the old town of Findhorn. On the coast of Kincardineshire, an illustration was afforded, at the close of the last century, of the effect of promontories in protecting a line of low shore. The village of Mathers, two miles south of Johnshaven, was built on an ancient shingle beach, protected by a projecting ledge of limestone rock. This was quarried for lime to such an extent, that the sea broke through, and in 1795 carried away the whole village in one night, and penetrated one hundred and fifty yards inland, where it has maintained its ground ever since, the new village having been built farther inland on the new shore. In the Bay of Montrose, we find the North Esk and the South Esk rivers pouring annually into the sea large quantities of sand and pebbles, yet they have formed no deltas; for the tides scour out the channels, and the current, setting across their mouths, sweeps away all the materials. Considerable beds of shingle, brought down by the North Esk, are seen along the beach.

Proceeding southwards, we find that at Arbroath, in Forfarshire, which stands on a rock of red sandstone, gardens and houses have been carried away within the last thirty years by encroachments of the sea. It has become necessary to remove the lighthouses at the mouth of the estuary of the Tay, in the same county, at Button Ness, which were built on a tract of blown sand, the sea having encroached for three-quarters of a mile.

Force of Currents in Estuaries.—A good illustration was afforded, during the building of the Bell Rock Lighthouse, at the mouth of the Tay, of the power which currents in estuaries can exert at considerable depths, in scouring out the channel. The Bell Rock is a sunken reef, consisting of red sandstone, being from twelve to sixteen feet under the surface at high water, and about twelve miles from the main land. At the distance of one hundred yards, there is a depth, in all directions, of two or three fathoms at low water. The perpendicular rise and fall of the spring tides is fifteen feet, and at neap tides eight feet; their velocity varying from one to three miles per hour. In 1807, during the erection of the lighthouse, six large blocks of granite, which had been landed on the reef, were removed by the force of the sea, and thrown over a rising ledge to the distance of twelve or fifteen paces; and an anchor, weighing about 22 cwt., was thrown up upon the rock *. Mr. Stevenson informs us, moreover, that drift stones, measuring upwards of thirty cubic feet, or more than two tons weight, have, during storms, been often thrown upon the rock from the deep water †.

Submarine forests.—Among the proofs that the sea has encroached both on the estuaries of the Tay and Forth, may be mentioned the submarine forests which have been traced for several miles by Dr. Fleming, along the margins of those estuaries on the north and south shores of the county of Fife ‡.

* Account of the Erection of the Bell Rock Lighthouse, p. 163.

† Ed. Phil. Journ., vol. iii. p. 54, 1820.

‡ Quarterly Journal of Science, &c., No. XIII. new series, March, 1830.

The alluvial tracts, however, on which such forests grow, generally occupy spaces which may be said to be in dispute between the river and the sea, and to be alternately lost and won. *Estuaries* (a term which we confine to inlets entered both by rivers and tides of the sea) have a tendency to become silted up *in parts;* but the same tracts, after remaining dry, perhaps, for thousands of years, are again liable to be overflowed, for they are always low, and, if inhabited, must generally be secured by artificial embankments. Meanwhile the sea devours, as it advances, the high as well as the low parts of the coast, breaking down, one after another, the rocky bulwarks which protect the mouths of estuaries. The changes of territory, therefore, within the general line of coast are all of a subordinate nature, in no way tending to arrest the march of the great ocean, nor to avert the destiny eventually awaiting the whole region; they are like the petty wars and conquests of the independent states and republics of Greece, while the power of Macedon was steadily pressing on, and preparing to swallow up the whole.

On the coast of Fife, at St. Andrew's, a tract of land which intervened between the castle of Cardinal Beaton and the sea has been entirely swept away, as were the last remains of the Priory of Crail, in the same county, in 1803. On both sides of the Frith of Forth, land has been consumed; at North Berwick in particular, and at Newhaven, where an arsenal and dock, built in the reign of James IV., in the fifteenth century, has been overflowed.

East coast of England.—If we now proceed to the English coast, we find records of numerous lands having been destroyed in Northumberland, as those near Bamborough and Holy Island, and at Tynemouth castle, which now overhangs the sea, although formerly separated from it by a strip of land. At Hartlepool, and several other parts of the coast of Durham composed of magnesian limestone, the sea has made considerable inroads. Almost the whole coast of Yorkshire, from the mouth of the Tees to that of the Humber, is in a state of gradual dilapidation. That part of the cliffs which consists of lias, the oolite

series, and chalk, decays slowly. They present abrupt and naked precipices, often three hundred feet in height; and it is only at a few points that the grassy covering of the sloping talus marks a temporary relaxation of the erosive action of the sea. The chalk cliffs are washed into caves in the projecting headland of Flamborough, where they are decomposed by the salt vapours, and slowly crumble away. But the waste is most rapid between that promontory and Spurn Point, or the coast of Holderness, as it is called. This tract consists chiefly of beds of clay, gravel, sand, and chalk rubble. The irregular intermixture of the argillaceous beds causes many springs to be thrown out, and this facilitates the undermining process, the waves beating against them, and a strong current setting chiefly from the north. The wasteful action is very conspicuous at Dimlington Height, the loftiest point in Holderness, where the beacon stands on a cliff one hundred and forty-six feet above high water, the whole being composed of clay, with pebbles scattered through it *.

Coast of Yorkshire.—In the old maps of Yorkshire, we find spots, now sand-banks in the sea, marked as the ancient sites of the towns and villages of Auburn, Hartburn, and Hyde. 'Of Hyde,' says Pennant, 'only the tradition is left; and near the village of Hornsea, a street called Hornsea Beck has long since been swallowed †.' Owthorne and its church have also been in great part destroyed, and the village of Kilnsea; but these places are now removed farther inland. The rate of encroachment at Owthorne, at present, is about *four yards a year* ‡. Not unreasonable fears are entertained that at some future time the Spurn Point will become an island, and that the ocean, entering into the estuary of the Humber, will cause great devastation §. Pennant, after speaking of the silting up of some ancient ports in that estuary, observes, 'But, in return,

* Phillips's Geology of Yorkshire, p. 61.

† Arctic Zoology, vol. i. p. 10, Introduction.

‡ For this information I am indebted to Mr. Phillips, of York.

§ Phillips's Geology of Yorkshire, p. 60.

the sea has made most ample reprisals; the site, and even the very names of several places, once towns of note upon the Humber, are now only recorded in history; and Ravensper was at one time a rival to Hull (Madox, Ant. Exch. i., 422), and a port so very considerable in 1332, that Edward Balliol and the confederated English Barons sailed from hence to invade Scotland; and Henry IV., in 1399, made choice of this port to land at, to effect the deposal of Richard II., yet the whole of it has long since been devoured by the merciless ocean: extensive sands, dry at low water, are to be seen in their stead *.'

Pennant describes Spurn Head as a promontory in the form of a sickle, and says the land, for some miles to the north, was 'perpetually preyed on by the fury of the German Sea, which devours whole acres at a time, and exposes on the shores considerable quantities of beautiful amber †.'

According to Bergmann, a strip of land, with several villages, was carried away near the mouth of the Humber in 1475.

Lincolnshire.—The maritime district of Lincolnshire consists chiefly of lands which lie below the level of the sea, being protected by embankments. Great parts of this fenny tract were, at some unknown period, a woody country, but were afterwards inundated, and are now again recovered from the sea. Some of the fens were embanked and drained by the Romans; but after their departure the sea returned, and large tracts were covered with beds of silt containing marine shells, now again converted into productive lands. Many dreadful catastrophes are recorded by incursions of the sea, whereby several parishes have been at different times overwhelmed.

Norfolk.—We come next to the cliffs of Norfolk and Suffolk, where the decay is in general incessant and rapid. At Hunstanton, on the north, the undermining of the lower arenaceous beds at the foot of the cliff causes masses of red and white chalk to be precipitated from above. Between Hunstanton

* Arct. Zool., vol. i. p. 10, Introduction. † Ibid.

and Weybourne, low hills, or dunes, of blown sand, are formed along the shore, from fifty to sixty feet high. They are composed of dry sand, bound in a compact mass by the long creeping roots of the plant called Marram (Arundo arenaria). Such is the present set of the tides, that the harbours of Clay, Wells, and other places, are securely defended by these barriers; affording a clear proof that it is not the strength of the material at particular points that determines whether the sea shall be progressive or stationary, but the general contour of the coast.

The waves constantly undermine the low chalk cliffs, covered with sand and clay, between Weybourne and Sherringham, a certain portion of them being annually removed. At the latter town I ascertained, in 1829, some facts which throw light on the rate at which the sea gains upon the land. It was computed, when the present inn was built, in 1805, that it would require seventy years for the sea to reach the spot; the mean loss of land being calculated, from previous observations, to be somewhat less than one yard annually. The distance between the house and the sea was fifty yards; but no allowance was made for the slope of the ground being *from* the sea, in consequence of which, the waste was naturally accelerated every year, as the cliff grew lower, there being at each succeeding period less matter to remove when portions of equal area fell down. Between the years 1824 and 1829, no less than seventeen yards were swept away, and only a small garden was then left between the building and the sea. There is now a depth of twenty feet (sufficient to float a frigate) at one point in the harbour of that port, where, only forty-eight years ago, there stood a cliff fifty feet high, with houses upon it! If once in half a century an equal amount of change were produced at once by the momentary shock of an earthquake, history would be filled with records of such wonderful revolutions of the earth's surface, but, if the conversion of high land into deep sea be gradual, it excites only local attention. The flag-staff of the Preventive Service station, on the south side of this

harbour, has, within the last fifteen years, been thrice removed inland, in consequence of the advance of the sea.

Farther to the south we find cliffs, composed, like those of Holderness before mentioned, of alternating strata of blue clay, gravel, loam, and fine sand. Although they sometimes exceed two hundred feet in height, the havoc made on the coast is most formidable. The whole site of ancient Cromer now forms part of the German Ocean, the inhabitants having gradually retreated inland to their present situation, from whence the sea still threatens to dislodge them. In the winter of 1825, a fallen mass was precipitated from near the lighthouse, which covered twelve acres, extending far into the sea, the cliffs being two hundred and fifty feet in height *. The undermining by springs has sometimes caused large portions of the upper part of the cliffs, with houses still standing upon them, to give way, so that it is impossible, by erecting breakwaters at the base of the cliffs, permanently to ward off the danger.

On the same coast, the ancient villages of Shipden, Wimpwell, and Eccles, have disappeared; several manors and large portions of neighbouring parishes having, piece after piece, been swallowed up; nor has there been any intermission, from time immemorial, in the ravages of the sea along a line of coast twenty miles in length, in which these places stood †. Hills of blown sand, between Eccles and Winterton, have barred up and excluded the tide for many hundred years from the mouths of several small estuaries; but there are records of nine breaches from twenty to one hundred and twenty yards wide, having been made through these, whereby immense damage was done to the low grounds in the interior. A few miles south of Happisburgh, also, are hills of blown sand, which extend to Yarmouth; and these are supposed to protect the coast, but in fact their formation proves that a temporary respite of the incursions of the sea on this part is permitted by the present set of the tides and currents. Were it otherwise, the land, as we have seen, would give way, though made of solid rock.

* Taylor's Geology of East Norfolk, p. 32. † Ibid.

Silting up of Estuaries.—At Yarmouth, the sea has not advanced upon the sands in the slightest degree since the reign of Elizabeth. In the time of the Saxons, a great estuary extended as far as Norwich, which city is represented, even in the thirteenth and fourteenth centuries, as 'situated on the banks of an arm of the sea.' The sands whereon Yarmouth is built first became firm and habitable ground about the year 1008, from which time a line of dunes has gradually increased in height and breadth, stretching across the whole entrance of the ancient estuary, and obstructing the ingress of the tides so completely, that they are only admitted by the narrow passage which the river keeps open, and which has gradually shifted several miles to the south. The tides at the river's mouth only rise, at present, to the height of three or four feet.

By the exclusion of the sea, thousands of acres in the interior have become cultivated lands; and, exclusive of smaller pools, upwards of sixty fresh-water lakes have been formed, varying in depth from fifteen to thirty feet, and in extent from one acre to twelve hundred *. The Yare, and other rivers, frequently communicate with these sheets of water; and thus they are liable to be filled up gradually with lacustrine and fluviatile deposits, and to be converted into land covered with forests. When the sea at length returns (for as the whole coast gives way, this must inevitably happen sooner or later), these tracts will be again submerged, and submarine forests may then be found, as along the margins of many estuaries. We may easily conceive that such natural embankments as those thrown by the waves, and subsequently raised by winds, across the entrance of this river, may so shut out the tide, that inland places may become dry which, on the breaching of the barrier, might again be permanently overflowed even at low water; for the tides are now so depressed, even outside the barrier, that the river is almost in the condition of one which enters an inland sea. Were high tides to recur, the fresh water would

* Taylor's Geology of East Norfolk, p. 10.

be ponded back during the flow, and would perhaps not entirely escape during the ebb.

Submarine forests.—It has been observed, by Dr. Fleming, that the roots of the trees in several submarine forests in Scotland are in lacustrine silt. The stumps of the trees evidently occupy the position in which they formerly grew, and are sometimes from eight to ten feet below high-water mark. The horizontality of the strata, and other circumstances, preclude the supposition of a slide, and the countries in question have been from time immemorial free from violent earthquakes, which might have produced subsidences. He has, therefore, attributed the depression, with much probability, to the drainage of peaty soil on the removal of a seaward barrier. Suppose a lake (like one of those in the valley of the Yare) to become a marsh, and a stratum of vegetable matter to be formed on the surface, of sufficient density to support trees. Let the outlet of the marsh be elevated a few feet only above the rise of the tide. All the strata below the level of the outlet would be kept constantly wet or in a semifluid state, but if the tides rise in the estuary, and the sea encroaches, portions of the gained lands are swept away, and the extremities of the alluvial and peaty strata, whereon the forest grew, are exposed to the sea, and at every ebb tide left dry to a depth equal to the increased fall of the tide. Much water, formerly prevented from es c api by the altitude of the outlet, now oozes out from the moist beds,—the strata collapse and the surface of the morass, instead of remaining at its original height, sinks below the level of the sea *.

Yarmouth does not project beyond the general line of coast which has been rounded off by the predominating current from the north-west. It must not be imagined, therefore, that the acquisition of new land fit for cultivation in Norfolk and Suffolk indicates any permanent growth of the eastern limits of

* See two papers by the Rev. Dr. Fleming, in the Trans. Roy. Soc. Edin., vol. ix. p. 419, and Quarterly Journ. of Sci., No. 13, new series, March, 1830. For further remarks on Submarine forests, see vol. ii., chap. 16.

our island, to compensate its reiterated losses. No *delta* can form on such a shore.

Coast of Suffolk.—The cliffs of Suffolk, to which we next proceed, are somewhat less elevated than those of Norfolk, but composed of similar accumulations of alternating clay, sand, and gravel. From Gorleston in Suffolk, to within a few miles north of Lowestoff, the cliffs are slowly undermined. Near the last-mentioned town, there is an inland cliff about sixty feet high, the talus being covered with turf and heath, between which and the sea is a low, flat tract of sand, called the Ness, which gains slowly on the sea. It does not seem difficult to account for the retreat of the sea at this point from its ancient limits, the base of the inland cliff. About a mile off Lowestoff lies the Holm Sand, the highest part of which is dry at low water. The current in the intervening passage, called Lowestoff Roads, is a back-water, wherein the tide, instead of obeying the general rule along this coast, runs nine hours towards the north, and only three towards the south. Here, therefore, we have an eddy, and the Holm Sand is a bank caused by the meeting of currents, where, as usual, sediment subsides. The channel called Lowestoff Roads is about a mile broad, and the depth varies from twenty to fifty-nine feet at low water. On one side, the current has hollowed out of the Holm Sand a deep curve, called the Hook, and on the other side, precisely opposite, is the projecting point of the Ness *. As the *points* and *bends* of a river correspond to each other, sand-bars being thrown up at each point, and the greatest depth being where the river is wearing into the bend, so we find here a shoal increasing at the Ness, and deep water preserved in the Hook. We cannot doubt that, at a modern period in the history of this coast, the high cliffs on which Lowestoff stands, were once continuous across the space where the roadstead now is, and where we have stated the present depth to be fifty-nine feet at low water.

By the mean of thirty-eight observations, it has been found

* See Plan of proposed Canal at Lowestoff, by Cubitt and Taylor, 1826.

that the difference of high and low tide at Lowestoff is only five feet eight inches*—a remarkably slight oscillation for our eastern coast, and which naturally suggests the inquiry whether, at other points where there are inland cliffs, the rise of the tides is below their average level.

Destruction of Dunwich by the Sea.—The sea undermines the high cliffs a few miles north of Lowestoff, near Corton; as also two miles south of the same town, at Pakefield, a village which has been in part swept away during the present century. From thence to Dunwich the destruction is constant. At the distance of two hundred and fifty yards from the wasting cliff at Pakefield, the sea is sixteen feet deep at low water, and in the roadstead beyond, twenty-four feet. Of the gradual destruction of Dunwich, once the most considerable sea-port on this coast, we have many authentic records. Gardner, in his history of that borough, published in 1754, shows, by reference to documents beginning with Doomsday Book, that the cliffs at Dunwich, Southwold, Eastern, and Pakefield, have been always subject to wear away. At Dunwich, in particular, two tracts of land which had been taxed in the eleventh century, in the time of King Edward the Confessor, are mentioned, in the Conqueror's survey, made but a few years afterwards, as having been devoured by the sea. The losses, at a subsequent period, of a monastery—at another of several churches—afterwards of the old port—then of four hundred houses at once—of the church of St. Leonard, the high road, town-hall, gaol, and many other buildings, are mentioned, with the dates when they perished. It is stated that, in the sixteenth century, not one quarter of the town was left standing; yet the inhabitants retreating inland, the name was preserved, as has been the case with many other ports when their ancient site has been blotted out. There is, however, a church, of considerable antiquity, still standing, the last of twelve mentioned in some records. In 1740, the laying open of the churchyard of St. Nicholas and St. Francis, in the sea-cliffs, is well described by Gardner, with

* These observations were made by Mr. R. C. Taylor.

the coffins and skeletons exposed to view,—some lying on the beach, and rocked

In cradle of the rude imperious surge.

Of these cemeteries no remains can now be seen. Ray also says, 'that ancient writings make mention of a wood a mile and a half to the east of Dunwich, the site of which must at present be so far within the sea *.' This city, once so flourishing and populous, is now a small village, with about twenty houses and one hundred inhabitants.

There is an old tradition, 'that the tailors sat in their shops at Dunwich, and saw the ships in Yarmouth Bay;' but when we consider how far the coast at Lowestoff Ness projects between these places, we cannot give credit to the tale, which, nevertheless, proves how much the inroads of the sea in times of old prompted men of lively imagination to indulge a taste for the marvellous.

Gardner's description of the cemeteries laid open by the waves reminds us of the scene which has been so well depicted by Bewick †, and of which numerous points on our coast might have suggested the idea. On the verge of a cliff, which the sea has undermined, are represented the unshaken tower and western end of an abbey. The eastern aisle is gone, and the pillars of the cloister are soon to follow. The waves have almost isolated the promontory, and invaded the cemetery, where they have made sport with the mortal relics, and thrown up a skull upon the beach. In the foreground is seen a broken tombstone, erected, as its legend tells, 'to *perpetuate* the memory' of one whose name is obliterated, as is that of the county for which he was 'Custos Rotulorum.' A cormorant is perched on the monument, defiling it, as if to remind some moralizer, like Hamlet, of 'the base uses' to which things sacred may be turned. Had this excellent artist desired to satirize certain popular theories of geology, he might have inscribed the stone to the memory of some philosopher who taught 'the perma-

* Consequences of the Deluge, Phys. Theol. Discourses.

† History of British Birds, vol. ii. p. 220, Ed. 1821.

nency of existing continents'—'the era of repose'—'the impotence of modern causes.'

South of Dunwich are two cliffs, called Great and Little Cat Cliff. That which bears the name of Great has become the smallest of the two, and is only fifteen feet high, the more elevated portion of the hill having been carried away; on the other hand, the Lesser Cat Cliff has gained in importance, for the sea has here been cutting deeper into a hill which slopes towards it. But at no distant period, the ancient names will again become appropriate, for at Great Cat Cliff the base of another hill will soon be reached, and at Little Cat Cliff the sea will, at about the same time, arrive at a valley.

The incursions of the sea at Aldborough were formerly very destructive, and this borough is known to have been once situated a quarter of a mile east of the present shore. The inhabitants continued to build farther inland, till they arrived at the extremity of their property, and then the town decayed greatly, but two sand-banks, thrown up at a short distance, now afford a temporary safeguard to the coast. Between these banks and the present shore, where the current now flows, the sea is twenty-four feet deep on the spot where the town formerly stood.

Continuing our survey of the Suffolk coast to the southward, we find that the cliffs of Bawdsey and Felixtow are foundering slowly, and that the point on which Landguard Fort is built suffers gradual decay. It appears that, within the memory of persons now living, the Orwell river continued its course in a more direct line to the sea, and entered to the north instead of the south of the low bank on which the fort last mentioned is built.

Essex.—Harwich, in Essex, stands on an isthmus, which will probably become an island in little more than half a century; for the sea will then have made a breach near Lower Dover Court, should it continue to advance as rapidly as it has done during the last fifty years. Within ten years, there was a considerable space between the battery at Harwich,

built twenty-three years ago, and the sea; part of the fortification has already been swept away, and the rest overhangs the water.

At Walton Naze, in the same county, the cliffs, composed of London clay, capped by the shelly sands of the crag, reach the height of about one hundred feet, and are annually undermined by the waves. The old churchyard of Walton has been washed away, and the cliffs to the south are continually disappearing.

Isle of Sheppey.—On the coast bounding the estuary of the Thames, there are numerous examples both of the gain and loss of land. The Isle of Sheppey, which is now about six miles long by four in breadth, is composed of London clay. The cliffs on the north, which are from sixty to eighty feet high, decay rapidly, fifty acres having been lost within the last twenty years. The church at Minster, now near the coast, is said to have been in the middle of the island fifty years ago; and it is computed that, at the present rate of destruction, the whole isle will be annihilated in about another half century *. On the coast to the east of Sheppey stands the church of Reculver, upon a sandy cliff about twenty feet high. In the reign of Henry VIII. it is said to have been nearly a mile distant from the sea. In the 'Gentleman's Magazine,' there is a view of it about the middle of the last century, which still represents a considerable space as intervening between the north wall of the churchyard and the cliff †. About twenty years ago, the waves came within one hundred and fifty feet of the boundary of the churchyard, half of which has since been washed away. The church is now dismantled (1829), and is in great danger; several houses in a field immediately adjoining having been washed away.

Isle of Thanet.—In the Isle of Thanet, Bedlam Farm, belonging to the hospital of that name, has lost eight acres in the

* For this information I am indebted to W. Gunnell, Esq.

† Rev. W. Conybeare's Outlines of Geology, &c. p. 32.

last twenty years, the land being chalk from forty to fifty feet above the level of the sea. It has been computed, that the average waste of the cliff between the North Foreland and the Reculvers, a distance of about eleven miles, is not less than two feet per annum. The chalk cliffs on the south of Thanet, between Ramsgate and Pegwell Bay, have, on an average, lost three feet per annum for the ten last years.

Goodwin Sands.—The Goodwin Sands lie opposite this part of the Kentish coast. They are about ten miles in length, and are in some parts three, and in others seven miles distant from the shore, and, for a certain space, are laid bare at low water. When the erection of a lighthouse on these sands was in contemplation by the Trinity Board, twelve years since, it was found, by borings, that the bank consisted of fifteen feet of sand, resting on blue clay. An obscure tradition has come down to us, that the estates of Earl Goodwin were situated here, and some have conjectured that they were overwhelmed by the flood mentioned in the Saxon Chronicle, *sub anno* 1099. The last remains of an island, consisting, like Sheppey, of clay, may, perhaps, have been carried away about that time.

Coast of Kent.—In the county of Kent, there are other records of waste, at Deal; and at Dover, Shakspeare's Cliff, composed entirely of chalk, has suffered greatly, and continually diminishes in height, the slope of the hill being towards the land. About twenty years ago, there was an immense land-slip from this cliff, by which Dover was shaken as if by an earthquake. In proceeding from the northern parts of the German Ocean towards the Straits of Dover, the water becomes gradually more shallow, so that in the distance of about two hundred leagues, we pass from a depth of one hundred and twenty, to that of fifty-eight, thirty-eight, twenty-four, and eighteen fathoms. In the same manner, the English channel deepens progressively from Dover to its entrance, formed by the Land's End of England, and the Isle of Ushant on the coast of France; so that the strait between Dover and Calais

may be said to form a point of partition between two great inclined planes, forming the bottom of these seas *.

Straits of Dover.—Whether England was formerly united with France has often been a favourite subject of speculation; and in 1753 a society at Amiens proposed this as the subject of a prize essay, which was gained by the celebrated Desmarest, then a young man. He founded his principal arguments on the identity of composition of the cliffs on the opposite sides of the Channel, on a submarine chain extending from Boulogne to Folkestone, only fourteen feet under low water, and on the identity of the noxious animals in England and France, which could not have swum across the straits, and would never have been introduced by man. He also attributed the rupture of the isthmus to the preponderating violence of the current from the north †. It will hardly be disputed that the ocean might have effected a breach through the land which, in all probability once united our country to the continent, in the same manner as it now gradually forces a passage through rocks of the same mineral composition, and often many hundred feet high, upon our coast.

Although the time required for such an operation was probably very great, yet we cannot estimate it by reference to the present rate of waste on both sides of the Channel. For when, in the thirteenth century, the sea burst through the isthmus of Staveren, which formerly united Friesland with North Holland, it opened, in about one hundred years, a strait more than half as wide as that which divides England from France, after which the dimensions of the new channel remained almost stationary. The greatest depth of the straits between Dover and Calais is twenty-nine fathoms, which only exceeds by one fathom the greatest depth of the Mississippi at New Orleans. If the moving column of water in the great American river, which, as we before stated, does not flow rapidly, can maintain an open passage to that depth in its alluvial accumulations,

* Stevenson on the Bed of the German Ocean.—Ed. Phil. Journ., No. V. p. 45.

* Cuvier, Éloge de Desmarest.

still more might a channel of the same magnitude be excavated by the resistless force of the tides and currents of 'the ocean stream,'

ποταμοιο μεγα σθενος Ωκεανοιο.

At Folkestone, the sea eats away the chalk and subjacent strata. About the year 1716 there was a remarkable sinking of a tract of land near the sea, so that houses became visible at points near the shore from whence they could not be seen previously. In the description of this subsidence in the Philosophical Transactions, it is said, 'that the land consisted of a solid stony mass (chalk), resting on wet clay (galt), so that it slid forwards towards the sea, just as a ship is launched on tallowed planks.' It is also stated that, within the memory of persons then living, the cliff there had been washed away to the extent of ten rods *.

Encroachments of the sea at Hythe are also on record; but between this point and Rye there has been a gain of land within the times of history; the rich level tract called Romney Marsh, about ten miles in width and five in breadth, consisting of silt, having received great accession. It has been necessary, however, to protect it from the sea, from the earliest periods, by a wall. These additions of land are exactly opposite that part of the English Channel where the conflicting tides meet; for, as those from the north are the most powerful, they do not neutralize each other's force till they arrive at this distance from the straits. Rye, on the south of this tract, was once destroyed by the sea, but it is now two miles distant from it. The neighbouring town of Winchelsea was destroyed in the reign of Edward I., the mouth of the Rother stopped up, and the river diverted into another channel. In its old bed an ancient vessel, apparently a Dutch merchantman, was recently found. It was built entirely of oak, and much blackened †.

South Coast of England.—To pass over some points near

* Phil. Trans., 1716. † Edin. Journ. of Sci., No. xix. p. 56.

Hastings, where the cliffs have wasted at several periods, we arrive at the promontory of Beachy Head. Here a mass of chalk, three hundred feet in length, and from seventy to eighty in breadth, fell, in the year 1813, with a tremendous crash; and similar slips have since been frequent *.

Sussex.—About a mile to the west of the town of Newhaven the remains of an ancient entrenchment are seen, on the brow of Castle Hill. This earth-work was evidently once of considerable extent, but the greater part has been cut away. The cliffs, which are undermined here, are high; more than one hundred feet of chalk being covered by tertiary clay and sand, from sixty to seventy feet in thickness. In a few centuries the last vestiges of the plastic clay formation on the southern borders of the chalk of the South Downs on this coast will be annihilated, and future geologists will learn, from historical documents, the ancient geographical boundaries of groups of strata then no more. On the opposite side of the estuary of the Ouse, on the east of Newhaven harbour, a bed of shingle, composed of chalk flints, derived from the waste of the adjoining cliffs, had accumulated at Seaford for several centuries. In the great storm of November, 1824, this bank was entirely swept away, and the town of Seaford inundated. Another great beach of shingle is now forming from fresh materials.

The whole coast of Sussex has been incessantly encroached upon by the sea from time immemorial; and, although sudden inundations only, which overwhelmed fertile or inhabited tracts are noticed in history, the records attest an extraordinary amount of loss. During a period of no more than eighty years, there are notices of about *twenty* inroads, in which tracts of land of from twenty to *four hundred acres* in extent were overwhelmed at once; the value of the tithes being mentioned by Nicholas, in his Taxatio Ecclesiastica †. In the reign of Elizabeth, the town of Brighton was situated on that tract

* Webster, Geol. Trans., vol. iii. p. 192.

† Mantell, Geology of Sussex, p. 293.

where the chain-pier now extends into the sea. In the year 1665, twenty-two tenements had been destroyed under the cliff. At that period there still remained under the cliff one hundred and thirteen tenements, the whole of which were overwhelmed in 1703 and 1705. No traces of the ancient town are now perceptible, yet there is evidence that the sea has merely resumed its ancient position at the base of the cliffs, the site of the old town having been merely a beach abandoned by the ocean for ages.

Hampshire—Isle of Wight.—It would be endless to allude to all the localities on the Sussex and Hampshire coasts where the land has been destroyed; but we may point to the relation of the present shape and geological structure of the Isle of Wight, as attesting that it owes its present outline to the continued action of the sea. Through the middle of the island a high ridge of chalk strata, in a vertical position, runs in a direction east and west. This chalk forms the projecting promontory of Culver Cliff on the east, and of the Needles on the west; while Sandown Bay on the one side, and Compton Bay on the other, have been hollowed out of the softer sands and argillaceous strata, which are inferior to the chalk.

The same phenomena are repeated in the Isle of Purbeck, where the line of vertical chalk forms the projecting promontory of Handfast Point; and Swanage Bay marks the deep excavation made by the waves in the softer strata, corresponding to those of Sandown Bay.

Hurst Castle-bank.—The entrance of the Channel called the Solent is becoming broader by the waste of the cliffs in Colwell Bay; it is crossed for more than two-thirds of its width by the shingle bank of Hurst Castle, which is about seventy yards broad and twelve feet high, presenting an inclined plane to the west. This singular bar consists of a bed of rounded chalk flints, resting on an argillaceous base, always covered by the sea. The flints and a few other pebbles, intermixed, are exclusively derived from the waste of Hordwell, and other cliffs to the westward, where fresh-water marls, capped with a cover-

ing of chalk flints, from five to fifty feet thick, are rapidly undermined.

Storm of Nov. 1824.—In the great storm of November, 1824, this bank of shingle was moved bodily forwards for forty yards towards the north-east; and certain piles which served to mark the boundaries of two manors were found, after the storm, on the opposite side of the bar. At the same time many acres of pasture land were covered by shingle, on the farm of Westover, near Lymington.

The cliffs between Hurst Shingle Bar and the mouth of the Stour and Avon are undermined continually. Within the memory of persons now living, it has been necessary thrice to remove the coast-road farther inland. The tradition, therefore, is probably true, that the church of Hordwell was once in the middle of that parish, although now very near the sea. The promontory of Christ Church Head gives way slowly. It is the only point between Lymington and Poole Harbour, in Dorsetshire, where any hard stony masses occur in the cliffs. Five layers of large ferruginous concretions, somewhat like the septaria of the London clay, have occasioned a resistance at this point, to which we may ascribe the existence of this headland. In the mean time, the waves have cut deeply into the soft sands and loam of Poole Bay; and, after severe frosts, great land-slips take place, which by degrees become enlarged into narrow ravines, or chines, as they are called, with vertical sides. One of these chines, near Boscomb, has been deepened twenty feet within a few years. At the head of each there is a spring, the waters of which have been chiefly instrumental in producing these narrow excavations, which are sometimes from one hundred to one hundred and fifty feet deep.

The peninsulas of Purbeck and Portland are continually wasting away. In the latter, the soft argillaceous substratum (Kimmeridge clay) hastens the dilapidation of the superincumbent mass of limestone.

Isle of Portland.—In 1665, the cliffs adjoining the principal quarries in Portland gave way to the extent of one hundred

yards, and fell into the sea; and in December 1734, a slide to the extent of one hundred and fifty yards occurred on the east side of the isle, by which several skeletons, buried between slabs of stone, were discovered. But a much more memorable occurrence of this nature, in 1792, arising probably from the undermining of the cliffs, is thus described in Hutchins's History of Dorsetshire. 'Early in the morning the road was observed to crack: this continued increasing, and before two o'clock the ground had sunk several feet, and was in one continued motion, but attended with no other noise than what was occasioned by the separation of the roots and brambles, and now and then a falling rock. At night it seemed to stop a little, but soon moved again; and before morning, the ground, from the top of the cliff to the water-side, had sunk in some places fifty feet perpendicular. The extent of ground that moved was about *a mile and a quarter* from north to south, and six hundred yards from east to west.'

Formation of the Chesil bank.—Portland is connected with the main land by the Chesil Bank, a ridge of shingle about seventeen miles in length, and, in most places, nearly a quarter of a mile in breadth. The pebbles forming this immense barrier are chiefly of limestone; but there are many of quartz, jasper, chert, and other substances, all loosely thrown together. What is singular, they gradually diminish in size, from west to east—from the Portland end of the bank to that which attaches to the main land. The formation of this bar may probably be ascribed, like that of Hurst Castle, to a meeting of tides, or to a great eddy between the peninsula and the land. We have seen that slight obstructions in the course of the Ganges will cause, in the course of a man's life, islands many times larger than the whole of Portland, and which, in some cases, consist of a column of earth more than one hundred feet deep. In like manner we may expect the slightest impediment in the course of that tidal wave, which is sweeping away annually large tracts of our coast, to give rise to banks of sand and shingle many miles in length, if the transported

materials be intercepted in their passage to those submarine receptacles whither they are borne by the current. The gradual diminution in the size of the gravel as we proceed eastward, might probably admit of explanation, if the velocity of the tide or eddy at different points was ascertained; the rolled masses thrown up being largest where the motion of the water is most violent, or where they are deposited at the least distance from the rocks from which they were detached. The storm of 1824 burst over this bar with great fury, and the village of Chesilton, built upon the southern extremity of the bank, was overwhelmed, with many of the inhabitants *. The fundamental rocks whereon the shingle rests are found at the depth of a few yards only below the level of the sea.

Dorsetshire—Devonshire—Cornwall.—At Lyme Regis, in Dorsetshire, the 'Church Cliffs,' as they are called, consisting of lias, about one hundred feet in height, have gradually fallen away, at the rate of one yard a year, since 1800 †. The cliffs of Devonshire and Cornwall, which are chiefly composed of hard rocks, decay less rapidly. Near Penzance, in Cornwall, there is a projecting tongue of land, called the 'Green,' formed of granitic sand, from which more than thirty acres of pasture land have been gradually swept away in the course of the last two or three centuries ‡. It is also said that St. Michael's Mount, now an insular rock, was formerly situated in a wood several miles from the sea; and its old Cornish name, accord-

* This same storm carried away part of the Breakwater at Plymouth, and huge masses of rock were lifted from the bottom of the weather side, and rolled fairly to the top of the pile. It was in the same month, and also during a spring tide, that a great flood is mentioned on the coasts of England, in the year 1099. Florence of Worcester says, 'On the third day of the nones of Nov., 1099, the sea came out upon the shore, and buried towns and men very many, and oxen and sheep innumerable.' Also the Saxon Chronicle, already cited, for the year 1099, 'This year eke on St. Martin's-mass day, the 11th of Novembre, sprung up so much of the sea flood, and so myckle harm did, as no man minded that it ever afore did, and there was the ylk day a new moon.'

† This ground was measured by Dr. Carpenter, of Lyme, in 1800, and again in 1829, as I am informed by Miss Mary Anning, of Lyme.

‡ Boase, Trans. Royal Geol. Soc. of Cornwall, vol. ii. p. 129.

ing to Carew, signifies the Hoare Rock in the Wood. Between the Mount and Newlyn, there is seen, under the sand, black vegetable mould, full of hazel nuts, and the branches, leaves, roots, and trunks of forest trees, all of indigenous species. This vegetable stratum has been traced seaward as far as the ebb permits, and seems to indicate some ancient estuary on that shore.

Tradition of loss of land in Cornwall.—The oldest historians mention a celebrated tradition in Cornwall, of the submersion of the Lionnesse, a country which formerly stretched from the Land's End to the Scilly Islands. The tract, if it existed, must have been thirty miles in length, and perhaps ten in breadth. The land now remaining on either side is from two hundred to three hundred feet high; the intervening sea about three hundred feet deep. Although there is no evidence for this romantic tale, it probably originated in some catastrophe occasioned by former inroads of the Atlantic upon this exposed coast *.

West coast of England.—Having now laid before the reader an ample body of proofs of the destructive operations of tides and currents on our eastern and southern shores, it will be unnecessary to enter into details of changes on the western coast, for they present merely a repetition of the same phenomena, and in general on an inferior scale. On the borders of the estuary of the Severn, the flats of Somersetshire and Gloucestershire have received enormous accessions, while on the other hand, submarine forests on the coast of Lancashire indicate the overflowing of alluvial tracts. There are traditions in Pembrokeshire † and Cardiganshire ‡ of far greater losses of territory than that which the Lionnesse tale of Cornwall pretends to commemorate. They are all important, as demon strating that the earliest inhabitants were familiar with the phenomenon of incursions of the sea.

* Boase, Trans. Royal Geol. Soc. of Cornwall, vol ii. p. 130.

† Camden, who cites Gyraldus, also Ray, 'On the Deluge,' Phys. Theol. p. 228,

‡ Meyrick's Cardigan.

Loss of land on the coast of France.—The French coast, particularly that of Brittany, where the tides rise to an extraordinary height, is the constant prey of the waves. In the ninth century many villages and woods are reported to have been carried away, the coast undergoing great change, whereby the hill of St. Michael was detached from the main land. The parish of Bourgneuf, and several others in that neighbourhood, were overflowed in the year 1500. In 1735, during a great storm, the ruins of Palnel were seen uncovered in the sea*. A romantic tradition, moreover, has descended from the fabulous ages, of the destruction of the south-western part of Brittany, whence we may probably infer some great inroad of the sea at a remote period †.

* Hoff, Geschichte, &c. vol. i. p. 49. † Ibid., p. 48.

CHAPTER XVI.

Action of Tides and Currents, *continued*—Inroads of the sea upon the delta of the Rhine in Holland—Changes in the arms of the Rhine—Estuary of the Bies Bosch, formed in 1421—Formation of the Zuyder Zee, in the 13th century—Islands destroyed—Delta of the Ems converted into a Bay—Estuary of the Dollart formed—Encroachment of the sea on the coast of Sleswick—Inroads on the Eastern shores of North America—Tidal wave, called the Bore—Influence of tides and currents on the mean level of seas—Action of currents in inland lakes and seas—Baltic—Cimbrian deluge—Straits of Gibraltar—Under-currents—Shores of Mediterranean—Rocks transported on floating icebergs—Dunes of blown sand—Sands of the Libyan Desert—De Luc's natural chronometers.

ACTION OF TIDES AND CURRENTS, *continued.*

Inroads of the sea upon the delta of the Rhine.—The line of British coast considered in the preceding chapter offered no example of the conflict of two antagonist forces; the entrance, on the one hand, of a river draining a large continent, and on the other, the flux and reflux of the tide, aided by a strong current setting across a river's mouth. But when we pass over by the Straits of Dover to the continent, and proceed northwards, we find an admirable illustration of such a contest, where the Rhine and the ocean are opposed to each other, each disputing the ground now occupied by Holland; the one striving to shape out an estuary, the other to form a delta. There was evidently a period when the river obtained the ascendency, but for the last two thousand years, during which man has witnessed and actively participated in the struggle, the result has been in favour of the ocean, the area of the whole territory having become more and more circumscribed; natural and artificial barriers having given way, one after another, and many hundred thousand human beings having perished in the waves.

Changes in the arms of the Rhine.—The Rhine, after flowing from the Grison Alps, copiously charged with sedi-

ment, first purges itself in the Lake of Constance, where a large delta is formed; then, swelled by the Aar and numerous other tributaries, it flows for more than six hundred miles towards the north; when, entering a low tract, it divides into two arms, not far north of Cleves—a point which must therefore be considered the head of its delta. The left arm takes the name of the Waal, and the right, retaining that of the Rhine, sends off another branch to the left, called the Leck, and still lower down, another named the Yssel. After this last division, the smallest stream, still called the Rhine, passes by Utrecht, and loses itself in the sands before reaching the German Sea, a few miles below Leyden. It is common, in all great deltas, that the principal channels of discharge should shift from time to time; but in Holland so many magnificent canals have been constructed, and have diverted, from time to time, the course of the waters, that the geographical changes in this delta are endless; and their history, since the Roman era, forms a complicated topic of antiquarian research. The present head of the delta is about forty geographical miles from the nearest part of the gulf called the Zuyder Zee, and more than twice that distance from the general coast-line. The present head of the Nilotic delta is about eighty or ninety geographical miles from the sea; that of the Ganges, as we before stated, two hundred and twenty; and that of the Mississippi about one hundred and eighty, reckoning from the point where the Atchafalaya branches off, to the extremity of the new tongue of land in the Gulf of Mexico. But the comparative distance between the heads of deltas and the sea affords scarcely any data for estimating the relative magnitude of the alluvial tracts formed by their respective rivers. For the ramifications depend on many varying and temporary circumstances, and the area over which they extend does not hold any constant proportion to the volume of water in the river.

We may consider the Rhine, at present, as having three mouths,—the southernmost or left arm being the Waal; the Leck, the largest of the three, being in the centre; and the

Yssel forming the right or northern arm. As the whole coast to the south, as far as Calais, and on the north, to the entrance of the Baltic, has, with few exceptions, from time immemorial, yielded to the force of the waves, it is evident that the delta of the Rhine, if it had advanced, would have become extremely prominent, and even if it had remained stationary, would long ere this have projected, like that strip of land already described, at the mouth of the Mississippi, beyond the rounded outline of the coast. But we find, on the contrary, that a line of islands which skirts the coast have not only lessened in size, but in number also, while great bays in the interior have been formed by incursions of the sea. We shall confine ourselves to the enumeration of some of the leading facts, in confirmation of these views, and begin with the southernmost part of the delta where the Waal enters, which is at present united with the Meuse, in the same manner as an arm of the Po, before mentioned, has become confluent with the Adige. The Meuse itself had once a common embouchure with the Scheldt, by Sluys and Ostburg, but this channel was afterwards sanded up, as were many others between Walcheren, Beveland, and other isles at the mouths of these rivers. The new accessions were almost all within the coast-line, and were far more than counterbalanced by inroads of the sea, whereby large tracts of land, and dunes of blown sand, together with towns and villages, were swept away between the fourteenth and eighteenth centuries. Besides the destruction of parts of Walcheren, Beveland, and populous districts in Kadzand, the island Orisant was in the year 1658 annihilated.

Inroads of the sea in Holland.—One of the most memorable eruptions occurred in 1421, where the tide, pouring into the mouth of the united Meuse and Waal, burst through a dam in the district named Bergse-Veld, and overflowed twenty-two villages, forming that large sheet of water called the Bies Bosch. No vestige even of the ruins of these places could ever afterwards be seen, but a small portion of the new bay became afterwards silted up, and formed an island. The Leck, or central arm of

the Rhine, which enters the sea a little to the north of this new estuary, has, at present, a communication with it. The island Grunewert, which in the year 1228 existed not far from Houten, has been entirely destroyed. Farther to the north is a long line of shore covered with sand dunes, where great depredations have been made from time to time. The church of Scheveningen, not far from the Hague, was once in the middle of the village, and now stands on the shore; half the place having been overwhelmed by the waves in 1570. Catwyck, once far from the sea, is now upon the shore; two of its streets having been overflowed, and land torn away to the extent of two hundred yards in 1719. It is only by aid of embankments, that Petten, and several other places farther north, have been defended against the sea.

Formation of the Zuyder Zee.—We may next examine the still more important changes which have taken place on the coast opposite the right arm of the Rhine or the Yssel, where the ocean has burst through a large isthmus, and entered the inland lake Flevo, which, in ancient times, was, according to Pomponius Mela, formed by the overflowing of the Rhine over certain low lands. It appears that, in the time of Tacitus, there were several lakes in the present site of the Zuyder Zee, between Friesland and Holland. The successive inroads by which these, and a great part of the adjoining territory, were transformed into a great gulf, began about the beginning, and were completed towards the close of the thirteenth century. Alting gives the following relation of the occurrence, drawn from manuscript documents of contemporary inhabitants of the neighbouring provinces. In the year 1205, the island now called Wieringen, to the south of the Texel, was still a part of the main land, but during several high floods, of which the dates are given, ending in December, 1251, it was separated from the continent.

Formation of the Straits of Staveren.—By subsequent incursions, the sea consumed great parts of the rich and populous isthmus, a low tract which stretched on the north of Lake

Flevo, between Staveren in Friesland, and Medemblick in Holland, till at length a breach was completed about the year 1282, and afterwards widened. Great destruction of land took place when the sea first broke in, and many towns were swept away; but there was afterwards a reaction to a certain extent, large tracts at first submerged having been gradually redeemed. The new straits south of Staveren are more than half the width of those of Dover, but are very shallow, the greatest depth not exceeding two or three fathoms. The new bay is of a somewhat circular form, and between *thirty* and *forty* miles in diameter. How much of this space may formerly have been occupied by Lake Flevo, is unknown.

Destruction of Islands.—A series of isles, stretching from the Texel to the mouths of the Weser and Elbe, are evidently the last relics of a tract once continuous. They have greatly diminished in size, and have lost about a third of their number, since the time of Pliny*. While the delta of the Rhine has suffered so materially from the action of tides and currents, it cannot be supposed that minor rivers should have been permitted to extend their deltas. It appears, that in the time of the Romans there was an alluvial plain of great fertility, where the Ems entered the sea by three arms. This low country stretched between Groningen and East Friesland, and sent out a peninsula to the north-east towards Emden. A flood, in 1277, first destroyed part of the peninsula. Other inundations

* Some few of them have extended their bounds, or become connected with others, by the sanding up of channels; but even these, like Juist, have generally given way as much on the north towards the sea, as they have gained on the south, or land side. Osterdun, Borkun, and several others, have been continually wasting away. Buissen is reduced to a sand-bank. Langeroog has been divided into three parts, and Wangeroog cut in two, many buildings have been carried away. Pliny counted twenty-three islands between the Texel and Eider, whereas there are now only sixteen, including Heligoland and Neuwerk.—Hoff. vol. i. p. 364. Heligoland at the mouth of the Elbe, began in the year 800 to be much consumed by the waves. In the years 1300, 1500, and 1649, other parts were swept away, till at last only a rock and some low ground remained. Since 1770, a current has cut a passage sufficiently deep to admit large ships through this remaining portion, and has formed two islands.—Hoff., vol. i. p. 57.

followed at different periods throughout the fifteenth century. In 1507, a part only of Torum, a considerable town, remained standing; and in spite of the erection of dams, the remainder of that place, together with market-towns, villages, and monasteries, to the number of fifty, were finally overwhelmed.

Formation of estuaries by the sea.—The new gulf, which was called the Dollart, although small in comparison to the Zuyder Zee, occupied no less than six square miles at first; but part of this space was, in the course of the two following centuries, again redeemed from the sea. The small bay of Leybucht, farther north, was formed in a similar manner in the thirteenth century, and the bay of Harlbucht in the middle of the sixteenth. Both of these have since been partially reconverted into dry land. Another new estuary, called the Gulf of Jahde, near the mouth of the Weser, scarcely inferior in size to the Dollart, has been gradually hollowed out since the year 1016, between which era and 1651 a space of about four square miles has been added to the sea. The rivulet which now enters this inlet is very small; but Arens conjectures, that an arm of the Weser had once an outlet in that direction.

Coast of Sleswick.—Farther north we find so many records of waste on the western coast of Sleswick, as to lead us to anticipate, that, at no distant period in the history of the physical geography of Europe, Jutland will become an island, and the ocean will obtain a more direct entrance into the Baltic. So late as 1825 the sea made a breach and entered the Lym-Fiord, so that the northern extremity of Jutland was converted for a time into an island; but the passage is now closed *.

Destruction of Northstrand by the sea, 1240.—Northstrand, up to the year 1240, was, with the islands Sylt and Föhr, so nearly connected with the main land as to appear a peninsula, and was called North Friesland, a highly cultivated and populous district. It measured from nine to eleven geographical miles from north to south, and six to eight from

* Malte-Brun, vol. viii. part 2, p. 572.

east to west. In the above-mentioned year it was torn asunder from the continent, and in part overwhelmed. The Isle of Northstrand, thus formed, was, towards the end of the sixteenth century, only four geographical miles in circumference, and was still celebrated for its cultivation and numerous population. After many losses, it still contained nine thousand inhabitants. At last, in the year 1634, on the evening of the 11th of October, a flood passed over the whole island, whereby one thousand three hundred houses, with many churches, were lost; fifty thousand head of cattle perished, and above six thousand men. Three small isles, one of them still called Northstrand, alone remained, which are now continually wasting.

A review of the ravages committed during the last two thousand years on the French, Dutch, and Danish coasts, naturally leads us to inquire how it happened that the Rhine was enabled, at some former period, to accumulate so large a delta. We might, perhaps, in reply to this question, repeat our former observation, that the set of tides and currents necessarily varies from time to time; and that different coasts become, each in their turn, exposed to their fury, and then again restored to a state of quiescence. Islands and promontories, moreover, may have disappeared, which once protected the present site of Holland; and that region may afterwards have been laid open, as the Baltic would be, if the ocean, by renewing its attacks, should finally breach the isthmus by Sleswick. It may also be suggested that if, in former times, the Straits of Dover were closed, the Rhine must have entered at the bottom of a deep bay, on the one side of which was Great Britain, and on the other the coasts of Norway, Denmark, the Netherlands, and France. The transporting power of the current might then have been much inferior to that afterwards exerted, when the tide ran freely through the channel. Pliny expressed his wonder that the new lands at the mouths of the Tigris and Euphrates grew so rapidly, and 'that the fluviatile matter was not swept away by the tide, which penetrated far above the tracts where great

accessions were made *.' The remark proves that he had considered the different condition of rivers in inland seas, and those discharging their waters into the ocean; but he did not reflect, that at the bottom of a deep bay where there is no current setting across the river's mouth, the ebbing and flowing of the waters cannot remove the sedimentary matter to a great distance.

Inroads of the sea on the Eastern shores of North America.—After so many authentic details respecting the destruction of the coast in parts of Europe best known, it will be unnecessary to multiply examples of analogous changes in more distant regions of the world. It must not, however, be imagined that our own seas form any exception to the general rule. Thus, for example, if we pass over to the Eastern coast of North America, where the tides rise to a great elevation, we find many facts attesting the incessant demolition of land. At Cape May, for example, on the north side of Delaware Bay, in the United States, the encroachment of the sea was shown by observations made consecutively for sixteen years, from 1804 to 1820, to average about nine feet a year †; and at Sullivan's Island, which lies on the north side of the entrance of the harbour of Charlestown, in South Carolina, the sea carried away a quarter of a mile of land in three years, ending in 1786 ‡.

Tidal wave called 'the Bore.'—Before we conclude our remarks on the action of the tides, we must not omit to mention the wave called 'the Bore,' which is a sudden and abrupt influx of the tide into a river or narrow strait. Those rivers are most subject to this wave which have the greatest embouchures in proportion to the size of their channels; because, in that case, a larger proportion of tide is forced through a passage comparatively smaller. For this reason, the Bristol Channel is very subject to the Bore, where it is of almost daily occurrence, and

* Nec ullâ in parte plus aut celerius profecere terræ fluminibus invectæ. Magis id mirum est, æstu longè ultra id accedente non repercussas.—Hist. Nat., lib. vi. c. 27.

† New Monthly Mag., vol. vi. p. 69.

‡ Hoff, vol. i. p. 96.

at spring tides rushes up the estuary with extraordinary rapidity. The same phenomenon is frequently witnessed in the principal branches of the Ganges, and in the Megna. 'In the Hoogly, or Calcutta river,' says Rennell, 'the Bore commences at Hoogly Point, the place where the river first contracts itself, and is perceptible above Hoogly Town; and so quick is its motion, that it hardly employs four hours in travelling from one to the other, though the distance is nearly seventy miles. At Calcutta it sometimes occasions an instantaneous rise of five feet; and both here, and in every other part of its track, the boats, on its approach, immediately quit the shore, and make for safety to the middle of the river. In the channels, between the islands in the mouth of the Megna, the height of the Bore is said to exceed twelve feet; and is so terrific in its appearance, and dangerous in its consequences, that no boat will venture to pass at spring tide*.' These waves may sometimes cause inundations, undermine cliffs, and still more frequently sweep away trees and land animals from low shores, whereby they may be carried down, and ultimately imbedded in submarine deposits.

Influence of tides and currents on the mean level of seas.— There is another question, in regard to the effects of tides and currents, not yet fully determined—how far they may cause the mean level of the ocean to vary at particular parts of the coast. It has been supposed, that the waters of the Red Sea maintain a constant elevation of between four and five fathoms above the neighbouring waters of the Mediterranean, at all times of the tide; and that there is an equal, if not greater diversity, in the relative levels of the Atlantic and Pacific, on the opposite sides of the isthmus of Panama. But the levellings recently carried across that isthmus by Mr. Lloyd, to ascertain the relative height of the Pacific Ocean at Panama, and of the Atlantic at the mouth of the river Chagres, have shown, that the difference of mean level between those oceans is not considerable. According to the result of this survey, on

* Rennell, Phil. Trans., 1781.

which great dependence may be placed *, the mean height of the Pacific is three feet and a half, or 3·52 above the Atlantic, if we assume the mean level of the sea to coincide with the mean between the extremes of the elevation and depression of the tides. For between the extremes of elevation and depression of the greatest tides in the Pacific, at Panama, there is a difference of 27·44 feet; but the mean difference at the usual spring tides is 21·22 feet: whereas at Chagres this difference is only 1·16 feet, and is the same at all seasons of the year.

The tides, in short, in the Caribbean Sea are scarcely perceptible, not exceeding those in some parts of the Mediterranean, whereas the rise is very high in the bay of Panama. But astronomers are agreed that, on mathematical principles, the rise of the tidal wave above the mean level of a particular sea must be greater than the fall below it; and although the difference has been hitherto supposed insufficient to cause an appreciable error, it is, nevertheless, worthy of observation, that the error, such as it may be, would tend to reduce the difference, small as it is, now inferred, from the observations of Mr. Lloyd, to exist between the levels of the two oceans. It is scarcely necessary to remark how much all points relating to the permanence of the mean level of the sea must affect our reasoning on the phenomena of estuary deposits; and it is to be hoped that further experiments will be made to ascertain the amount of irregularity, if any exist.

ACTION OF CURRENTS IN INLAND LAKES AND SEAS.

Coast of the Baltic.—In such large bodies of water as the North American lakes, the continuance of a strong wind in one direction often causes the elevation of the water and its accumulation on the leeward side; and while the equilibrium is

* Mr. Lloyd received from General Bolivar a special commission to survey the isthmus of Panama, with the view of ascertaining the most eligible line of communication between the two seas. He was assisted by Capt. Falmarck, a Swedish officer of engineers; and the result of their labours will appear in the Philosophical Transactions.

being restored, powerful currents are occasioned. By this means the finer sedimentary particles, as we before mentioned, are borne far out from the deltas, and argillaceous and calcareous marls are formed far from the shores. In the Euxine, also, although free from tides, we learn from Pallas, that there is a sufficiently strong current to undermine the cliffs in many parts, and particularly in the Crimea. But the force of currents is exerted in a much more powerful degree in seas like the Mediterranean and the Baltic, where strong currents set in from the ocean, whether driven in during tempests or from other more constant causes. The current which runs through the Cattegat, or channel of communication between the German Ocean and the Baltic, not only commits dreadful devastations on the isles of the Danish Archipelago, but acts, though with less energy, on the coasts far in the interior, as, for example, in the vicinity of Dantzic. Thus, in the year 1800, near the village of Jershoft a great mass was projected by a landslip into the sea. Hela, a point of land running out before Dantzic, was formerly much broader than at present; and farther north, in Samland, woods and territories have been torn away by the sea *.

The continuance of north-westerly gales and storms in the Atlantic, during the height of the spring tides, has often been attended with the most fatal disasters on the Danish coast, where, during the last ten centuries, we find authentic accounts of the wearing down of promontories, the deepening of gulfs, the conversion of peninsulas into islands, and the waste of isles; while in several cases marsh land, defended for centuries by dikes, has at last been overflowed, and thousands of the inhabitants whelmed in the waves.

Thus the island Barsoe, on the coast of Sleswick, has lost, year after year, an acre at a time. The island Alsen suffers in like manner. The peninsula Zingst was converted into an island in 1625. There is a tradition that the isle of Rugen was originally torn by a storm from the main land of Pome-

* Hoff, vol. i. p. 73, who cites Pisansky.

rania; and it is known, in later times, to have lost ground, as in the year 1625, when a tract of land was carried away. Some of the islands which have wasted away consist of ancient alluvial accumulations, containing blocks of granite, which are also spread over the neighbouring main land. The Marsh Islands are mere banks, like the lands formed of the 'warp' in the Humber, protected by dikes. Some of them, after having been inhabited with security for more than ten centuries, have been suddenly overwhelmed. In this manner, in 1216, no less than ten thousand of the inhabitants of the Eyderstede and Ditmarsch perished; and on the 11th of October, 1634, the islands and the whole coast as far as Jutland suffered by a dreadful deluge.

Cimbrian Deluge.—We have before enumerated the ravages of the ocean on the western shores of Sleswick, and we find memorials of a series of like catastrophes on the eastern coast of that peninsula; so that we can scarcely doubt that a large opening will, at some future period, connect the Baltic with the North Sea. Jutland was the Cimbrica Chersonesus of the ancients, and was then evidently the theatre of similar calamities; for Florus says, 'Cimbri, Theutoni, atque Tigurini, ab extremis Galliæ profugi, cum terras eorum inundasset Oceanus, novas sedes toto orbe quærebant *.' Some have wished to connect this 'Cimbrian deluge' with the bursting of the isthmus between England and France, and with other supposed convulsions; but when we consider the annihilation of Heligoland and Northstrand, and the other terrific inundations in Jutland and Holstein since the Christian era, wherein thousands have perished, we need not resort to any such extraordinary catastrophes to account for the historical relation. The wave which in 1634 devastated the whole coast of Jutland committed such havoc, that we must be cautious how we reject hastily the traditions of like events on the coasts of Kent, Cornwall, Pembrokeshire, and Cardigan; for, however sceptical we may be

* Lib. iii. cap. 3.

as to the amount of territory destroyed, it is very possible that former inroads of the sea may have been greater on those shores than any witnessed in modern times.

Straits of Gibraltar.—It is well known that a powerful current sets constantly from the Atlantic into the Mediterranean, and its influence extends along the whole southern borders of that sea, and even to the shores of Asia Minor. Captain Smyth found, during his survey, that the central current ran constantly at the rate of from three to six miles an hour eastward into the Mediterranean, the body of water being three miles and a half wide. But there are also two lateral currents —one on the European, and one on the African side; each of them about two miles and a half broad, and flowing at about the same rate as the central stream. These lateral currents ebb and flow with the tide, setting alternately into the Mediterranean and into the Atlantic. The escape of the great body of water, which is constantly flowing in, has usually been accounted for by evaporation, which must be very rapid and copious in the Mediterranean; for the winds blowing from the shores of Africa are hot and dry, and hygrometrical experiments recently made in Malta and other places show that the mean quantity of moisture in the air investing the Mediterranean is equal only to one half of that in the atmosphere of England.

Deposition of Salt in the Mediterranean.—It is, however, objected, that evaporation carries away only fresh water, and that the current is continually bringing in salt water: why, then, do not the component parts of the waters of the Mediterranean vary? or, why do they remain apparently the same as those of the ocean? Some have imagined that the excess of salt might be carried away by an under-current running in a contrary direction to the superior; and this hypothesis appeared to receive confirmation from a late discovery that the water taken up about fifty miles within the Straits, from a depth of six hundred and seventy fathoms, contained a quantity of salt *four times greater* than the water of the surface.

Dr. Wollaston *, who analysed this water obtained by Captain Smyth, truly inferred that an under-current of such denser water, flowing outward, if of equal breadth and depth with the current near the surface, would carry out as much salt below as is brought in above, although it moved with less than one-fourth part of the velocity, and would thus prevent a perpetual increase of saltness in the Mediterranean beyond that existing in the Atlantic. It was also remarked by others, that the result would be the same if, the swiftness being equal, the inferior current had only a fourth of the volume of the superior. At the same time there appeared reason to conclude that this great specific gravity was only acquired by water at immense depths; for two specimens of the water taken at the distance of some hundred miles from the Straits, and at depths of four hundred, and even four hundred and fifty fathoms, were found by Dr. Wollaston not to exceed in density that of many ordinary samples of sea-water. Such being the case, we can now prove that the vast amount of salt brought into the Mediterranean *does not* pass out again by the Straits. For it appears by Captain Smyth's soundings, which Dr. Wollaston had not seen, that between the Capes of Trafalgar and Spartel, which are twenty-two miles apart, and where the Straits are shallowest, the deepest part, which is on the side of Cape Spartel, is only *two hundred and twenty fathoms.* It is therefore evident that if water sinks in certain parts of the Mediterranean, in consequence of the increase of its specific gravity, to greater depths than two hundred and twenty fathoms, it can never flow out again into the Atlantic, since it must be stopped by the submarine barrier which crosses the shallowest part of the Straits of Gibraltar.

What, then, becomes of the excess of salt?—for this is an inquiry of the highest geological interest. The Rhone, the Po, and many hundred minor streams and springs, pour annually into the Mediterranean large quantities of carbonate of lime,

* On the Water of the Mediterranean, by W. H. Wollaston, M.D., F.R.S., Phil. Trans., 1829, part i. p. 29.

together with iron, magnesia, silica, alumina, sulphur, and other mineral ingredients, in a state of chemical solution. To explain why the influx of this matter does not alter the composition of this sea has never been thought to present a great difficulty; for it is known that calcareous rocks are forming in the delta of the Rhone, in the Adriatic, on the coast of Asia Minor, and in other localities. Precipitation is acknowledged to be the means whereby the surplus mineral matter is disposed of, after the consumption of a certain portion in the secretions of testacea and zoophytes. But some have imagined that, before muriate of soda can, in like manner, be precipitated, the whole Mediterranean ought to become as much saturated with salt as the brine-springs of Cheshire, or Lake Aral, or the Dead Sea.

There is, however, an essential difference between these cases; for the Mediterranean is not only incomparably greater in extent than the two last-mentioned basins, but its depth is enormous. In the narrowest part of the Straits of Gibraltar, where they are about nine miles broad, between the Isle of Tariffa and Alcanzar Point, the depth varies from one hundred and sixty to five hundred fathoms; but between Gibraltar and Ceuta, Captain Smyth sounded to the extraordinary depth of *nine hundred and fifty fathoms!* where he found a gravelly bottom, with fragments of broken shells. Saussure sounded to the depth of two thousand feet, within a few yards of the shore, at Nice. What profundity, then, may we not expect some of the central abysses of this sea to reach! The evaporation being, as we before stated, very rapid, the surface water becomes impregnated with a slight excess of salt; and its specific gravity being thus increased it instantly falls to the bottom, while lighter water rises to the top, or that introduced by rivers, and by the current from the Atlantic, flows over it. But the heavier fluid does not merely fall to the bottom, but when it arrives there continues to flow on till it reaches the lowest part of a submarine abyss, to which additional supplies of brine must annually be carried, so that the lower strata of

water may be almost or quite saturated, while the surface of the superincumbent column, four or five miles, perhaps, in height, being continually renewed by rivers and a current from the ocean, remains impregnated with the usual quantity of salt. Under such circumstances we may suppose precipitation to take place not in thin films, such as are said to cover the alluvial marshes along the western shores of the Euxine, nor in minute layers, like those of the salt 'étangs' of the Rhone, but on the grandest scale—continuous masses of pure rock-salt, extending, perhaps, for hundreds of miles in length, like those in the mountains of Poland, Hungary, Transylvania, and Spain *.

To those who consider that there cannot possibly be any deposition even at the greatest depth until the whole Mediterranean is saturated, we may suggest that volcanic heat may give rise to evaporation at the bottom of the ocean. It is true that the entrance of hot springs, or even of steam above the boiling temperature, would be insufficient, for that would only cause ascending and descending currents which might assist the intermixture of the upper and lower portions; but if there were solfataras or rents through which hot vapours escaped,

* As to the existence of an inferior current flowing westward, none of the experiments made in the late survey give any countenance whatever to this popular notion; and it seems most unnecessary to resort to it, not only because the expenditure of the Mediterranean by evaporation must be immense, but because it is not yet proved that the two lateral currents, which conjointly exceed in breadth that of the centre, do not restore the equilibrium, if occasionally disturbed. They ebb and flow with the tide, but they may carry more water to the west than to the east. The opinion, that in the middle of the Straits the water returned into the Atlantic by a submarine counter-current, first originated in the following circumstance. M. Du l'Aigle, commander of a privateer called the Phœnix, of Marseilles, gave chase to a Dutch merchant-ship, near Ceuta Point, and came up with her in the middle of the gut, between Tariffa and Tangier, and there gave her one broadside, which directly sunk her. A few days after, the sunk ship, with her cargo of brandy and oil, arose on the shore near Tangier, which is at least four leagues to the westward of the place where she sank, and directly against the strength of the *central* current.—Phil. Trans., 1724. It seems obvious that the ship in this case was brought back by one of the *lateral* currents, not by an *under* current.

which we know continue in certain places emitting flames for ages, salt water might be converted into steam in the fissure, and salt might be precipitated in the space from which the steam was expelled. Suppose additional supplies of sea-water to find their way into the rent laterally, the vast superincumbent pressure of the ocean injecting the fluid into every pore and crevice of the rock; a repetition of the process might take place and this fissure might be filled with salt, after which precipitation would go on along the bottom of the sea. In this case there might be afterwards no apparent connexion between the mass of salt and the subjacent source of subterranean heat.

The Straits of Gibraltar are said to become gradually wider by the wearing down of the cliffs on each side at many points; and the current sets along the coast of Africa so as to cause considerable inroads in various parts, particularly near Carthage. Near the Canopic mouth of the Nile, at Aboukir, the coast was greatly devastated in the year 1784, when a small island was nearly consumed. By a series of similar operations, the old site of the cities of Nicopolis, Taposiris, Parva, and Canopus, have become a sandbank *.

Rocks transported by floating Icebergs.—Marine currents are sometimes instrumental in the transportation of rock and soil, by floating large masses of ice to great distances from the shore. When glaciers in northern latitudes descend the valleys burdened with alluvial debris, and arrive at the shore, they are frequently detached, and float off. Scoresby † counted five hundred icebergs in latitude 69° and 70° north, rising above the surface from the height of one to two hundred feet, and measuring from a few hundred yards to a mile in circumference. Many of these contained strata of earth and stones, or were loaded with beds of rock of great thickness, of which the weight was conjectured to be from fifty thousand to one hundred thousand tons. As the mass of ice below the level of the water is between seven and eight times greater than that

* Clarke's Travels in Europe, Asia, and Africa, vol. iii., pp. 340 and 363, 4th edition.

† Voyage in 1822, p. 233.

above, these masses may sometimes take the ground in great numbers, in particular parts of the sea, and may, as they dissolve, deposit such masses of matter on particular parts of the bottom of the deep, or on the shores of some isles, as may offer perplexing problems to future geologists. Some ice islands have been known to drift from Baffin's Bay to the Azores, as we before stated, and from the South Pole to the immediate neighbourhood of the Cape of Good Hope.

Sand Hills.—It frequently happens, where the sea is encroaching on a coast, that perpendicular cliffs of considerable height, composed of loose sand, supply, as they crumble away, large quantities of fine sand, which being in mid-air when detached, are carried by the winds to great distances, covering the land or barring up the mouths of estuaries. This is exemplified in Poole Bay, in Hampshire, and in many points of the coast of Norfolk and Suffolk. But a violent wind will sometimes drift the sand of a sea-beach, and carry it up with fragments of shells to great heights, as in the case of the sands of Barry, at the northern side of the estuary of the Tay, where hills of this origin attain the height of one hundred and forty feet.

On the coast of France and Holland long chains of these dunes have been formed in many parts, and often give rise to very important geological changes, by barring up the mouths of estuaries, and preventing the free ingress of the tides, or free efflux of river water.

About the year 1500 the shifting sands at the mouth of the Adour at Bayonne were suddenly thrown, by a violent storm, across the mouth of that river. The Adour flowing back upon itself forced a new passage to the northward, along the sandy plain of Capbreton, till at last it reached the sea at Boucau, at the distance of *seven leagues* from the point where it had formerly entered. It was not till the year 1579 that the celebrated architect, Louis de Foix, was directed by Henry III. to attempt the re-opening of the ancient channel, which he effected with great difficulty *.

* Nouvelle Chronique de la Ville de Bayonne, pp. 113, 139. 1827.

Chains of sand-hills have also accumulated on the shores of the delta of the Nile, especially opposite the Lakes of Brulos and Menzala, forming mounds whereby the waters of these lakes are retained *. By the alternate formation and destruction of such barriers, fresh-water and marine deposits may sometimes be formed in succession on the same spots, and afterwards be laid dry by the exclusion of the tides, and be again submerged when high tides break into the estuary again. Many of the phenomena of submarine forests may, perhaps, admit of explanation, when the effects of such barriers of sand have been more carefully studied. The loose sand often forms a firm mass when bound together by the roots of plants fitted for such a soil, particularly the Arundo arenaria, and Elymus arenarius.

A considerable tract of cultivated land on the north coast of Cornwall has been inundated by drift sand, forming hills several hundred feet above the level of the sea, and composed of comminuted marine shells. By the shifting of the sands in that county, the ruins of ancient buildings have been discovered; and in some cases where they have been bored to a great depth, distinct strata, separated by a vegetable crust, are visible. In some localities, as at New Quay, large masses have become sufficiently indurated to be used for architectural purposes. The lapidification, which is still in progress, appears to be due to oxide of iron held in solution by the water which percolates the sand †. Terrestrial shells are found enclosed entire in this rock.

Drift sand of the African deserts.—The moving sands of the African deserts have been driven by the west winds over all the lands capable of tillage on the western banks of the Nile, except such as are sheltered by mountains ‡. The ruins of ancient cities are buried under these sands between the Temple of Jupiter Ammon and Nubia. M. G. A. De Luc

* Rennell's Herodotus.

† Boase on the Submersion of part of the Mount's Bay, &c. Trans. Roy. Geol. Society of Cornwall, vol. ii. p. 140.

‡ M. G. A. De Luc, Mercure de France, Sept. 1809.

attempted to infer the recent origin of our continents, from the fact that the sands of the desert have only arrived in modern times at the fertile plains of the Nile. This scourge, he said, would have afflicted Egypt for ages anterior to the times of history, if the continents had risen above the level of the sea several hundred centuries before our era *. But the author proceeded in his chronological computations, on a multitude of gratuitous assumptions, not one of which were explicitly stated. He ought, in the first place, to have demonstrated that the whole continent of Africa was raised above the level of the sea at one period; for unless this point was established, the region from whence the sands began to move might have been the last addition made to Africa, and the commencement of the sand-flood might have been long posterior to the formation of the greater portion of that continent. That the different parts of Europe were not all elevated at one time, is now generally admitted. De Luc should also have pointed out the depth of drift sand in various parts of the great Lybian deserts, and have shown whether any valleys of large dimensions had been filled up,—how long these arrested the progress of the sands, and how far the flood had upon the whole advanced since the times of history. If, in the absence of all these necessary elements of the computation, the doctrines of this author, respecting 'natural chronometers,' were extremely popular, and that, too, in an age when close reasoning and rigorous investigation were applied to other branches of physical science, it only proves how strong were the prepossessions in regard to time which impeded the progress of geology.

There is not one great question relating to the former changes of the earth and its inhabitants into which considerations of *time* do not enter; and as violent prejudices existed on this important topic for three hundred years after the first cultivation of geology, we cannot wonder that sound and enlightened views were so long in meeting with general reception.

* De Luc, Mercure de France, Sept. 1809.

CHAPTER XVII.

Reproductive effects of Tides and Currents—Silting up of Estuaries does not compensate the loss of land on the borders of the ocean—Bed of the German Ocean—Composition and extent of its sand-banks—Strata deposited by currents on the southern and eastern shores of the Mediterranean—Transportation by currents of the sediment of the Amazon, Orinoco, and Mississippi—Stratification—Concluding remarks.

REPRODUCTIVE EFFECTS OF TIDES AND CURRENTS.

From the facts enumerated in the last chapter, it will appear that, on the borders of the ocean, currents co-operating with tides are most powerful instruments in the destruction and transportation of rocks; and as numerous tributaries discharge their alluvial burden into the channel of one great river, so we find that many great rivers often deliver their earthy contents to one marine current, to be borne by it to a distance, and deposited in some deep receptacle of the ocean. The current not only receives this tribute of sedimentary matter from streams draining the land, but acts also itself on the coast, as does a river on the cliffs which bound a valley. The course of currents on the British shores is ascertained to be as tortuous as that of ordinary rivers. Sometimes they run between sand-banks which consist of matter thrown down at certain points where the velocity of the stream had been retarded; but it very frequently happens, that as in a river one bank is made of alluvial gravel, while the other is composed of some hard rock constantly undermined, so the current, in its bends, strikes here and there upon a coast which then forms one bank, while a shoal under water forms the other. If the coast be composed of solid materials, it yields slowly, or if of great height, it does not lose ground rapidly, since a large quantity of matter must then be removed before the sea can penetrate to any distance. But the openings where rivers enter are generally the points

of least resistance, and it is here, therefore, that the ocean makes the widest and longest breaches.

But a current alone cannot shape out and keep open an estuary, because it holds in suspension, like the river, during certain seasons of the year, a large quantity of sediment; and when their waters, flowing in opposite directions, meet, this matter subsides. For this reason, in inland seas, and even on the borders of the ocean, where the rise of the tide happens to be slight, it is scarcely possible to prevent a harbour from silting up; and it is often expedient to carry out a jetty to beyond the point where the marine current and the river neutralise each other's force, for beyond this point a free channel is maintained by the superior force of the current.

Estuaries, how formed.—The formation and keeping open of large estuaries are due to the *combined influence* of tides and currents; for when the tide rises, a large body of water suddenly enters the mouth of the river, where, becoming confined within narrower bounds, while its momentum is not destroyed, it is urged on, and, having to pass through a contracted channel, rises and runs with increased velocity, just as a swollen river when it reaches the arch of a bridge scarcely large enough to give passage to its waters, is precipitated in a cataract, while rushing through the arch. During the ascent of the tide, a stream of fresh water is flowing down from the higher country, and is arrested for several hours; and thus a large lake of brackish water is accumulated, which, as soon as the ebb causes the sea to fall, is let loose, as on the removal of an artificial sluice or dam. By the force of this retiring body of water, the alluvial sediment, both of the river and of the sea, is swept away, and transported to such a distance from the mouth of the estuary, that a small part only can return with the next tide.

Tides in Estuaries.—In the estuary of the Thames at London, and in the Gironde, the tide flows five hours and ebbs seven, and in all estuaries the water requires a longer time to run down than up; so that the preponderating force is always

in the direction which tends to keep open a deep and broad passage. But as it is evident that both the river and the tidal current are ready to part with their sediment whenever their velocity is checked, there is naturally a tendency in all estuaries to silt up partially, since the causes of retardation are very numerous, and constantly change their position.

The new lands acquired within the mouth of an estuary are only a few feet above the mean level of the sea, whereas cliffs of great height are consumed every year. If, therefore, the area of land annually abandoned by the sea in estuaries were equal to that invaded by it, there would still be no compensation *in kind.*

Silting up of estuaries does not compensate for loss of coasts.—Many writers have declared that the gain on our eastern coast, since the earliest periods of history, has more than counterbalanced the loss; but they have been at no pains to calculate the amount of the latter, and have often forgotten that, while the new acquisitions are manifest, there are rarely any natural monuments to attest the former existence of what is now no more. They have also taken into their account those tracts artificially recovered, which are often of great agricultural importance, and may remain secure, perhaps, for thousands of years, but which are nevertheless exposed to be overflowed again by a small proportion of the force required to remove the high lands of our shores. It will seem, at first sight, somewhat paradoxical, but it is nevertheless true, that the greater number of estuaries, although peculiarly exposed to the invasion of the sea, are usually contracting in size, even where the whole line of coast is giving way. But the fact is, that the inroads made by the ocean upon estuaries, although extremely great, are completed during periods of comparatively short duration; and in the intervals between these visitations, the mouths of rivers, like other parts of the coast, usually enjoy a more or less perfect respite.

All the estuaries, taken together, constitute but a small part of a great line of coast; it is, therefore, most probable, that if our observations extend to a few centuries only, we

shall not see any, and very rarely all, of this small part exposed to the fury of the ocean. The coast of Holland and Friesland, if studied for several consecutive centuries since the Roman era, would generally have led to the conclusion that the land was encroaching fast upon the sea, and that the aggrandizement within the estuaries far more than compensated the losses on the open coast. But when our retrospect embraces the whole period, an opposite inference is drawn; and we find that the Zuyder Zee, the Bies Bosch, Dollart, and Yahde, are modern gulfs and bays, and that these points have been the principal theatres of the retreat, instead of the advance, of the land. If we possessed records of the changes on our coast for several thousand years, they would probably present us with similar results; and although we have hitherto seen our estuaries, for the most part, become partially converted into dry land, and portions of bold cliffs intervening between the mouths of rivers consumed by the sea, this has merely arisen from the accidental set of the currents and tides during a brief period.

The current which flows round from the north-west, and bears against our eastern coast, transports, as we have seen, materials of various kinds. It undermines and sweeps away the granite, gneiss, trap rocks, and sandstone of Shetland, and removes the gravel and loam of the cliffs of Holderness, Norfolk, and Suffolk, which are between fifty and two hundred feet in height, and which waste at the rate of from one to six yards annually. It bears away the strata of London clay on the coast of Essex and Sheppey—consumes the chalk with its flints for many miles continuously on the shores of Kent and Sussex—commits annual ravages on the fresh-water beds, capped by a thick covering of chalk flints in Hampshire, and continually saps the foundations of the Portland limestone. It receives, besides, during the rainy months, large supplies of pebbles, sand, and mud, which numerous streams from the Grampians, Cheviots, and other chains, send down to the sea. To what regions, then, is all this matter consigned? It is not retained in mechanical suspension by the waters of the sea, nor does it mix with them

in a state of chemical solution,—it is deposited *somewhere*, yet certainly not in the immediate neighbourhood of our shores; for, in that case, there would soon be a cessation of the encroachment of the sea, and large tracts of low land, like Romney Marsh, would almost everywhere encircle our island. As there is now a depth of water, exceeding thirty feet, in some spots where cities flourished but a few centuries ago, it is clear that the current not only carries far away the materials of the wasted cliffs, but tears up besides many of the regular strata at the bottom of the sea.

Filling up of the German Ocean.—The German Ocean is deepest on the Norwegian side, where the soundings give one hundred and ninety fathoms; but the mean depth of the whole basin may be stated at only about thirty-one fathoms*. The bed of this sea is traversed by several enormous banks, one of which, occupying a central position, trends from the Frith of of Forth, in a north-easterly direction, to a distance of one hundred and ten miles; others run from Denmark and Jutland upwards of one hundred and five miles to the north-west; while the greatest of all, the Dogger Bank, extends for upwards of three hundred and fifty-four miles from north to south. The whole superfices of these enormous shoals is equal to about one-fifth of the whole area of the German Ocean, or to about one-third of the whole extent of England and Scotland†. The average height of the banks measures, according to Mr. Stevenson, about seventy-eight feet; the upper portion consisting of fine and coarse siliceous sand, mixed with fragments of corals and shells ground down, the proportion of the calcareous ingredients being very great ‡.

In a late survey of the North Sea, conducted by Captain Hewett, the shallowest parts of the Doggerbank were found to be forty-two feet under water, except in one place, where there had been a wreck; so that we may suppose that the currents, which vary in their velocity from a mile to two miles and a half

* Stevenson, on the Bed of the German Ocean, or North Sea.—Ed. Phil. Journ., No. V. p. 44, 1820. † Ibid., p. 47. ‡ Ibid.

per hour, to have power to prevent the accumulation of drift matter in places of less depth. We learn from the same hydrographer, that there are long narrow ravines intersecting some of these banks, which are very precipitous at their sides. One of these varies from seventeen to forty-four fathoms in depth, and in a part called 'the inner silver pits,' is fifty-five fathoms deep. These facts lead decidedly to the inference that the banks are not composed bodily of loose materials, but are hills of solid matter covered with drift sand, and separated by narrow valleys, which must be already filled up in part with drift sand or mud.

So great is the quantity of matter held in suspension by the tidal current on our shores, that the waters are in some places artificially introduced into certain lands below the level of the sea; and by repeating this operation, which is called 'warping,' for two or three years, considerable tracts have been raised, in the estuary of the Humber, to the height of about six feet. Large quantities of coarse sand and pebbles are also drifted along at the bottom: and when such a current meets with any deep depression in the bed of the ocean, it must necessarily fill it up; just as a river, when it meets with a lake in its course, fills it gradually with sediment. But in the one case, the sheet of water is converted into land, whereas, in the other, a shoal only will be raised, overflowed at high water, or at least by spring tides. The only records which we at present possess of the gradual shallowing of seas are confined, as might be expected, to estuaries, havens, and certain channels of no great depth; and to some inland seas, as the Baltic, Adriatic, and Arabian Gulf. It is only of late years that accurate surveys and soundings have afforded data of comparison in very deep seas, of which future geologists will avail themselves.

Strata deposited by currents.—It appears extraordinary that in some tracts of the sea, adjoining our coast, where we know that currents are not only sweeping along rocky masses, thrown down, from time to time, from the high cliffs, but scouring out also deep channels in the regular strata, there should exist

fragile shells and tender zoophytes in abundance, which live uninjured by these violent movements. The ocean, however, is in this respect a counterpart of the land; and as, on our continents, rivers may undermine their banks, uproot trees, and roll along sand and gravel, while their waters are inhabited by testacea and fish, and their alluvial plains are adorned with rich vegetation and forests, so the sea may be traversed by rapid currents, and its bed may suffer great local derangement, without any interruption of the general order and tranquillity.

One important character in the formations produced by currents, is the immense extent over which they are the means of diffusing homogeneous mixtures; for these are often coextensive with a great line of coast, and, by comparison with their deposits, the deltas of rivers must shrink into insignificance. In the Mediterranean the same current which is rapidly destroying many parts of the African coast, between the Straits of Gibraltar and the Nile, preys also upon the Nilotic delta, and drifts the sediment of that great river to the eastward. To this source the rapid accretions of land on parts of the Syrian shores where rivers do not enter, may be attributed.

It is the opinion of M. Girard, one of the *savans* who accompanied Napoleon's expedition to Egypt, and were employed on the survey of the ancient canal of Amron, communicating between the Nile and the Red Sea, that the isthmus of Suez itself is merely a bar formed by the deposition of this current and of the Nile, and that the two seas were formerly united *. It is certain that the isthmus is daily gaining in width by the accession of fresh deposits on the shores of the Mediterranean †.

The ruins of ancient Tyre are now far inland, and those of ancient Sidon are two miles distant from the coast, the modern town having been removed towards the sea ‡. But the south coast of Asia Minor affords far more striking examples of

* Déscription de l'Egypte, Mémoires, tom. i. p. 33.

† Quarterly Review, No. LXXXVI. p. 445.

‡ Hoff., vol. i. p. 253.

advances of the land upon the sea, where small streams co-operate with the current before mentioned. Captain Beaufort, in his Survey of that coast, has pointed out the great alterations effected on these shores since the time of Strabo, where havens are filled up, islands joined to the main land, and where the whole continent has increased many miles in extent. Strabo himself, on comparing the outline of the coast in his time with its ancient state, was convinced, like our countryman, that it had gained very considerably upon the sea. The new-formed strata of Asia Minor consist *of stone,* not of loose, incoherent materials. Almost all the streamlets and rivers, like many of those in Tuscany and the south of Italy, hold abundance of carbonate of lime in solution, and precipitate travertin, or sometimes bind together the sand and gravel into solid sandstones and conglomerates: every delta and sand-bar thus acquires solidity, which often prevents streams from forcing their way through them, so that their mouths are constantly changing their position *.

Distribution of the sediment of the Amazon by currents.— Among the greatest deposits now in progress, and of which the distribution is chiefly determined by currents, we may class those between the mouths of the Amazon and the southern coast of North America. It is well known that a great current is formed along the coast of Africa, by the water impelled by the Trade Winds blowing from the south. When this current reaches the head of the Gulf of Guinea, it is opposed by the waters brought to the same spot by the Guinea current, and it then streams off in a westerly direction, and pursues its rapid course quite across the Atlantic to the continent of South America. Here one portion proceeds along the northern coast of Brazil to the Caribbean Sea and the Gulf of Mexico. Captain Sabine found that this current was running with the astonishing rapidity of four miles an hour where it crosses the stream of the Amazon, which river preserves part

* Karamania, or a brief Description of the Coast of Asia Minor, &c. London, 1817.

of its original impulse, and its waters not wholly mingled with those of the ocean at the distance of three hundred miles from its mouth *. The sediment of the Amazon is thus constantly carried to the north-west as far as to the mouths of the Orinoco, and an immense tract of swamp is formed along the coast of Guiana, with a long range of muddy shoals bordering the marshes, and becoming converted into land †. The sediment of the Orinoco is partly detained, and settles near its mouth, causing the shores of Trinidad to extend rapidly, and is partly swept away into the Caribbean Sea by the equatorial current. According to Humboldt, much sediment is carried again out of the Caribbean Sea into the Gulf of Mexico. The rivers, also, which descend from the high platform of Mexico, between the mouths of the Norte and Tampico, when they arrive, swollen by tropical rains, at the edge of that platform, bear down an enormous quantity of rock and mud to the sea; but the current, setting across their mouths, prevents the growth of deltas, and preserves an almost uniform curve in that line of coast ‡. It must, therefore, exert a great transporting power, and it cannot fail to sweep away part of the matter which is discharged from the mouths of the Norte and the Mississippi.

Area over which strata may be formed by currents.—It follows from these observations, that, in certain parts of the globe, continuous formations are now accumulated over immense spaces along the bottom of the ocean. The materials undoubtedly must vary in different regions, yet for thousands of miles they may often retain some common characters, and be simultaneously in progress throughout a space stretching 30° of latitude from south-east to north-west, from the mouths of the Amazon, for example, to those of the Mississippi—as far as from the Straits of Gibraltar to Iceland. At the same time,

* Experiments to determine the Figure of the Earth, &c., p. 445.

† Lochead's Observations on the Nat. Hist. of Guiana. Edin. Trans., vol. iv.

‡ This coast has been recently examined by Captain Vetch.—See also Bauza's new chart of the Gulf of Mexico.

great coral reefs are growing around the West Indian islands; and in some parts, streams of lava are occasionally flowing into the sea, which become covered again, in the intervals between eruptions, with other beds of corals. The various rocks, therefore, stratified and unstratified, now forming in this part of the globe, may occupy, perhaps, far greater areas than any group of our ancient secondary series which has yet been traced through Europe.

In regard to the distribution of sediment by currents, we may observe, that the rate of subsidence of the finer mud carried down by every great river into the ocean, must be extremely slow; for the more minute the separate particles of mud, the slower will they sink to the bottom, and the sooner will they acquire what is called their terminal velocity. It is well known that a solid body descending through a resisting medium, falls by the force of gravity, which is constant, but its motion is resisted by the medium more and more as its velocity increases until the resistance becomes sufficient to counteract the further increase of velocity. For example, a leaden ball, one inch diameter, falling through air of density as at the earth's surface, will never acquire greater velocity than 260 feet, and, in water, its greatest velocity will be eight feet six inches, per second. If the diameter of the ball were $\frac{1}{100}$ of an inch, the terminal velocities in air would be 26 feet, and in water .86 of a foot per second.

Now, every chemist is familiar with the fact, that minute particles descend with extreme slowness through water. A precipitate of sulphate of baryta, for example, will sometimes require more than five or six hours to subside one inch*; while oxalate and phosphate of lime require nearly an hour to subside about an inch and a half and two inches respectively †.

When we recollect that La Place has estimated the mean depth of the Atlantic at three miles, and that the equatorial current runs through parts of that ocean at the rate of four miles an hour, and when at the same time we consider that

* On the authority of Mr. Faraday.

† On the authority of Mr. R. Phillips.

some fine mud carried down by rivers, as well as the impalpable powder showered down by volcanos, may only subside at the rate of an inch per hour, we shall be prepared to find examples of the transportation of sediment over areas of indefinite extent.

It is not uncommon for the emery powder used in polishing glass to take more than an hour to sink one foot. Suppose mud, composed of particles twice as coarse, to fall at the rate of two feet per hour, and these to be discharged into that part of the Gulf Stream which preserves a mean velocity of three miles an hour for a distance of 2000 miles; in twenty-eight days these particles will be carried 2016 miles, and will only have fallen to a depth of 224 fathoms.

We are assuming, however, that the current retains its superficial velocity at the depth of 224 fathoms, for which we have as yet no data. Experiments should be made to ascertain the rate of currents at considerable distances from the surface, and the time taken by the finest river-sediment to settle in sea-water of a given depth, and then the geologist may determine the area over which homogeneous mixtures may be simultaneously distributed in certain seas.

Stratification.—In regard to the internal arrangement of 'pelagian' formations deposited by currents far from the land, we may infer that in them, as in deltas, there is usually a division into strata; for, in both cases, the accumulations are successive, and, for the most part, interrupted. The waste of cliffs on the British coast is almost entirely confined to the winter months; so that running waters in the sea, like those on the land, are periodically charged with sediment, and again become pure. It will happen, in many cases, that the melting of snow will yield an annual tribute of fluviatile sediment in spring or summer, while violent gales of wind will cause the principal dilapidations on the shores to occur in autumn and winter; so that distinct materials may be arranged in alternate strata in deep depressions of the bed of the ocean.

Those geologists who are not averse to presume that the

course of Nature has been uniform from the earliest ages, and that causes now in action have produced the former changes of the earth's surface, will consult the ancient strata for instruction in regard to the reproductive effects of tides and currents. It will be enough for them to perceive clearly that great effects now annually result from the operations of these agents, in the inaccessible depths of lakes, seas, and the ocean; and they will then search the ancient lacustrine and marine strata for manifestations of analogous effects in times past. Nor will it be necessary for them to resort to very ancient monuments; for in certain regions where there are active volcanos, and where violent earthquakes prevail, we may examine submarine formations many thousand feet in thickness, belonging to our own era, or, at least, to the era of contemporary races of organic beings.

CHAPTER XVIII.

Changes of the inorganic world, *continued*—Igneous causes—Division of igneous agents into the volcano and the earthquake—Distinct regions of subterranean disturbance—Region of the Andes—System of volcanos extending from the Aleutian isles to the Moluccas—Polynesian archipelago—Volcanic region extending from the Caspian Sea to the Azores—Former connexion of the Caspian with Lake Aral and the Sea of Azof—Low steppes skirting these seas—Tradition of deluges on the shores of the Bosphorus, Hellespont, and the Grecian archipelago—Periodical alternation of earthquakes in Syria and Southern Italy—Western limits of the European region—Earthquakes rarer and more feeble in proportion as we recede from the centres of volcanic action—Extinct volcanos not to be included in lines of active vents.

CHANGES OF THE INORGANIC WORLD, *continued*—IGNEOUS CAUSES.

We have hitherto considered the changes wrought, since the times of history and tradition, by the continued action of aqueous causes on the earth's surface; and we have next to examine those resulting from igneous agency. As the rivers and springs on the land, and the tides and currents in the sea, have, with some slight modifications, been fixed and constant to certain localities from the earliest periods of which we have any records, so the volcano and the earthquake have, with few exceptions, continued, during the same lapse of time, to disturb the same regions. But as there are signs, on almost every part of our continent, of great power having been exerted by running water on the surface of the land, and by tides and currents on cliffs bordering the sea, where, in modern times, no rivers have excavated, and no tidal currents undermined—so we find signs of volcanic vents and violent subterranean movements in places where the action of fire has long been dormant. We can explain why the intensity of the force of aqueous causes should be developed in succession in different districts. Currents, for example, and tides, cannot destroy our coasts, shape out or silt up estuaries, break through isthmuses, and annihilate islands,

form shoals in one place and remove them from another, without the direction and position of their destroying and transporting power becoming transferred to new localities. Neither can the relative levels of the earth's crust, above and beneath the waters, vary from time to time, as they are admitted to have varied at former periods, and as we shall demonstrate that they still do, without the continents being, in the course of ages, modified, and even entirely altered, in their external configuration. Such events must clearly be accompanied by a complete change in the volume, velocity, and direction of the streams and land floods to which certain regions give passage. That we should find, therefore, cliffs where the sea once committed ravages, and from which it has now retired—estuaries where high tides once rose, but which are now dried up—valleys hollowed out by water, where no streams now flow, is no more than we should expect;—these and similar phenomena are the necessary consequences of physical causes now in operation; and we may affirm that, if there be no instability in the laws of Nature, similar fluctuations must recur again and again in time to come.

But however natural it may be that the force of running water in numerous valleys and of tides and currents in many tracts of the sea, should now be *spent*, it is by no means so easy to explain why the violence of the earthquake and the fire of the volcano should also have become locally extinct, at successive periods. We can look back to the time when the marine strata, whereon the great mass of Etna rests, had no existence; and that time is extremely modern in the earth's history. This alone affords ground for anticipating that the eruptions of Etna will one day cease.

> Nec quæ sulfureis ardet fornacibus Ætna
> Ignea semper erit, *neque enim fuit ignea semper*,

are the memorable words which are put into the mouth of Pythagoras by the Roman poet, and they are followed by speculations as to the cause of volcanic vents shifting their position. Whatever doubts the philosopher expresses as to

the nature of these causes, it is assumed, as incontrovertible, that the points of eruption will hereafter vary, *because they have formerly done so.*

We have endeavoured to show, by former chapters, how utterly this principle of reasoning is set at nought by the modern schools of geology, which not only refuse to conclude that great revolutions in the earth's surface are now in progress, or that they will take place hereafter, *because* they have often been repeated in former ages, but even assume the improbability of such a conclusion, and throw the whole weight of proof on those by whom that doctrine is embraced.

Division of the subject.—In our view of igneous causes we shall consider, first, the volcano, and afterwards the earthquake; for although both are probably the effects of the same subterranean process, they give rise to very different phenomena on the surface of the globe. Both are confined to certain regions, but the subterranean movements are least violent in the immediate proximity of volcanic vents, especially where the discharge of aëriform fluids and melted rock is made constantly from the same crater. We say that there are certain regions to which both the points of eruption, and the movements of great earthquakes are confined; and we shall begin by tracing out the geographical boundaries of some of these, that the reader may be aware of the magnificent scale on which the agency of subterranean fire is now simultaneously developed. Over the whole of the vast tracts alluded to, active volcanic vents are distributed at intervals, and most commonly arranged in a linear direction. Throughout the intermediate spaces there is abundant evidence that the subterranean fire is at work continuously, for the ground is convulsed from time to time by earthquakes; gaseous vapours, especially carbonic acid gas, are disengaged plentifully from the soil; springs often issue at a very high temperature, and their waters are very commonly impregnated with the same mineral matters which are discharged by volcanos during eruptions.

DISTINCT REGIONS OF SUBTERRANEAN DISTURBANCE.

Region of the Andes.—Of these great regions, that of the Andes is one of the best defined. Respecting its southern extremity, we are still in need of more accurate information, some conceiving it to extend into Terra del Fuego and Patagonia *. But if we begin with Chili, in the forty-sixth degree of south latitude, we find that, in proceeding from this point towards the north, to the twenty-seventh degree of north latitude, there is a line of volcanos so uninterrupted, that it is rare to find any intervening degree of latitude in which there is not an active vent. About twenty of these are now enumerated, but we may expect the number to augment greatly when the country has been more carefully examined, and throughout a longer period. How long an interval of rest entitles us to consider a volcano extinct, cannot yet be determined; but we know that, in Ischia, there intervened, between two consecutive eruptions, a pause of *seventeen centuries;* and a much longer period, perhaps, elapsed between the eruptions of Vesuvius before the earliest Greek colonies settled in Campania, and the renewal of its activity in the reign of Titus. It will be necessary, therefore, to wait for at least six times as many centuries as have elapsed since the discovery of America, before any one of the dormant craters of the Andes can be presumed to be entirely spent, unless there are some *geological* proofs of the late eruptions having belonged to a remote era.

The Chilian volcanos rise up through granitic mountains. Villarica, one of the principal, continues burning without intermission, and is so high that it may be distinguished at the distance of one hundred and fifty miles. A year never passes in this province without some slight shocks of earthquakes; and about once in a century, or oftener, tremendous convulsions occur, by which, as we shall afterwards see, the land has been shaken from one extremity to the other, and continuous tracts, together with the bed of the Pacific, have been raised

* Hoff, vol. ii. p. 447.

permanently from one to twenty feet and upwards above their former level. Hot springs are numerous in this district, as well as springs of naphtha and petroleum, and mineral waters of various kinds.

If we pursue our course northwards, we find in Peru only one active volcano as yet known; but the province is so subject to earthquakes, that scarcely a week happens without a shock, and many of these have been so considerable as to create great changes of the surface. Proceeding farther north, we find in the middle of Quito, where the Andes attain their highest elevation, from the second degree of south, to the third degree of north latitude, Tunguragua, Cotopaxi, Antisana, and Pichinca, the three former of which throw out flames not unfrequently. From fissures on the side of Tunguragua, a deluge of mud (moya) descended in 1797, and filled valleys a thousand feet wide to the depth of six hundred feet, forming barriers whereby rivers were dammed up, and lakes occasioned. Earthquakes have, in the same province, caused great revolutions in the physical features of the surface. Farther north, continuing the same line, there are three volcanos in the province of Pasto, and three others in that of Popayan. In the provinces of Guatimala and Nicaragua, which lie between the Isthmus of Panama and Mexico, there are no less than twenty-one active volcanos, all of them contained between the tenth and fifteenth degrees of north latitude.

The great volcanic chain, after having thus pursued its course for several thousand miles from south to north, turns off in a side direction in Mexico, and is prolonged in a great plateau, between the eighteenth and twenty-second degrees of north latitude. This high table-land owes its present form to the circumstance of an ancient system of valleys, in a chain of primary mountains, having been filled up to the depth of many thousand feet, with various volcanic products. Five active volcanos traverse Mexico from west to east—Tuxtla, Orizaba, Popocatepetl, Jorullo, and Colima. Jorullo, which is in the centre of the great plateau, is no less than forty leagues

from the nearest ocean—an important circumstance, as showing that the proximity of the sea is not a necessary condition, although certainly a very general characteristic, of the position of active volcanos. The extraordinary eruption of this mountain, in 1759, will be described in the sequel. If the line which connects these five vents be prolonged, in a westerly direction, it cuts the volcanic group of islands, called the Isles of Revillagigedo.

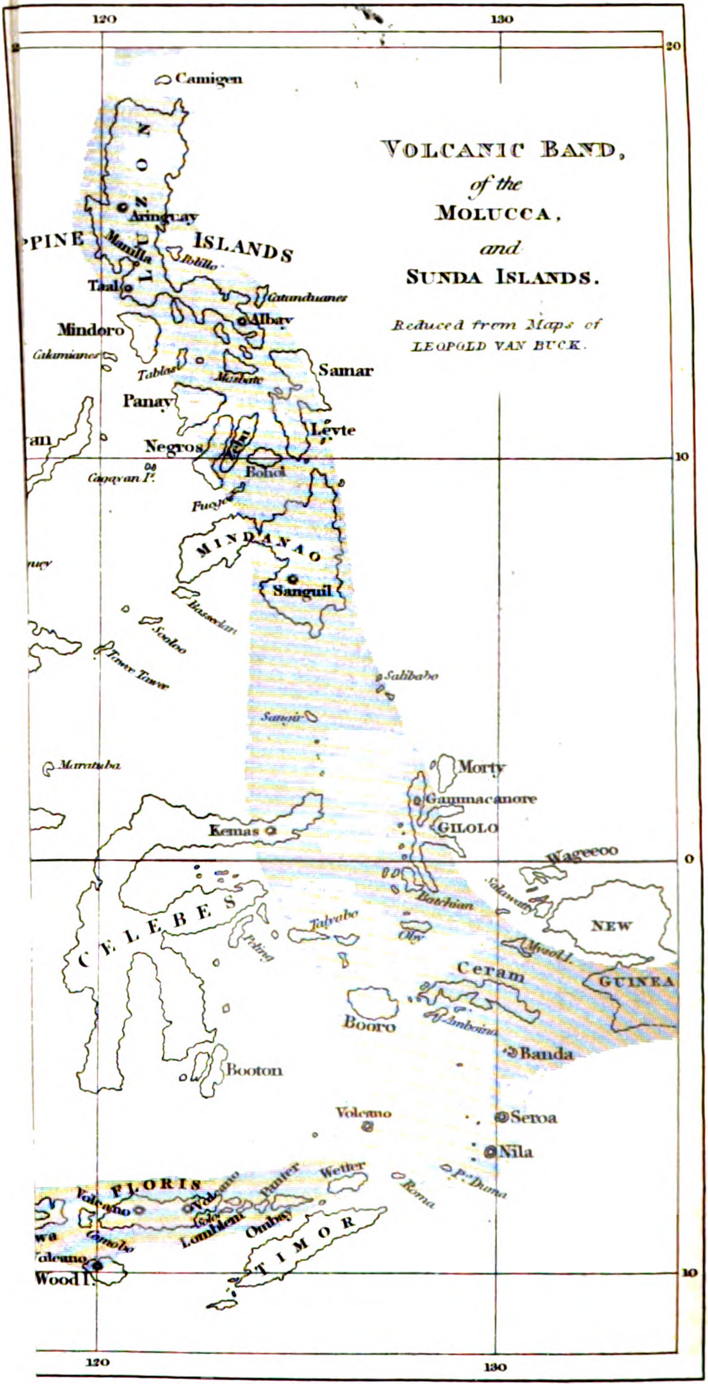
To the north of Mexico there are three, or according to some, five volcanos, in the peninsula of California, but of these we have at present no detailed account. We have before mentioned the violent earthquakes which in 1812 convulsed the valley of the Mississippi at New Madrid, for the space of three hundred miles in length. As this happened exactly at the same time as the great earthquake of Caraccas, it is probable that these two points are parts of one continuous volcanic region; for the whole circumference of the intervening Caribbean Sea must be considered as a theatre of earthquakes and volcanos. On the north lies the island of Jamaica, which, with a tract of the contiguous sea, has often experienced tremendous shocks; and these are frequent along a line extending from Jamaica to St. Domingo, and Porto Rico. On the south of the same basin the shores and mountains of Colombia are perpetually convulsed. On the west, is the volcanic chain of Guatimala and Mexico, before traced out; and on the east the West India isles, where, in St. Vincent's and Guadaloupe, are active vents.

Thus it will be seen that volcanos and earthquakes occur uninterruptedly, from Chili to the north of Mexico; and it seems probable, that they will hereafter be found to extend from Cape Horn to California, or even perhaps to New Madrid, in the United States—a distance upon the whole as great as from the pole to the equator. In regard to the eastern limits of the region, they lie deep beneath the waves of the Pacific, and must continue unknown to us. On the west they do not appear, except where they include the West Indian islands, to

be prolonged to a great distance, for there seem to be no indications of volcanic disturbances in Guiana, Brazil, and Buenos Ayres.

Volcanic region from the Aleutian Isles to the Moluccas.—On an equal, if not a still grander scale, is another continuous line of volcanic action, which commences, on the north, with the Aleutian Isles in Russian America, and extends, first in an easterly direction for nearly two hundred geographical miles, and then southwards, without interruption, throughout a space of between sixty and seventy degrees of latitude to the Moluccas, where it branches off in different directions both towards the east and north-west. The northern extremity of this volcanic region is the Peninsula of Alaska, in about the fifty-fifth degree of latitude. From thence the line is continued through the Aleutian or Fox Islands, to Kamtschatka. In that archipelago eruptions are frequent; and a new isle rose in 1814, which, according to some reports, is three thousand feet high and four miles round *. Earthquakes of the most terrific description agitate and alter the bed of the sea and surface of the land throughout this tract. The line is continued in the southern extremity of the peninsula of Kamtschatka, where there are seven active volcanos, which, in some eruptions, have scattered ashes to immense distances. The Kurile chain of isles constitutes the prolongation of the range, where a train of volcanic mountains, nine of which are known to have been in eruption, trends in a southerly direction. In these, and in the bed of the adjoining sea, alterations of level have resulted from earthquakes since the middle of the last century. The line is then continued to the south-west in the great Island of Jesso, where there are active volcanic vents, as also in Nipon, the principal of the Japanese group, where the number of burning mountains is very great; slight shocks of earthquakes being almost incessant, and violent ones experienced at distant intervals. Between the Japanese and Philippine Islands, the communication is preserved by several small insular vents. Sulphur

* Hoff, vol. ii. p. 414.



VOLCANIC BAND,
of the
MOLUCCA,
and
SUNDA ISLANDS.
Reduced from Maps of
LEOPOLD VAN BUCH.
120
130
20
10
0
Camigen
LUZON
Aringuay
PHILIPPINE ISLANDS
Manilla
Polillo
Taal
Catanduanes
Albay
Mindoro
Calamianes
Tablas
Masbate
Samar
Panay
Leyte
Negros
Zebu
Bohol
Cagayan I.
Fuego
MINDANAO
Sanguil
Basselan
Sooloo
Tawee Tawee
Salibabo
Sangir
Maratuba
Morty
Gammacanore
GILOLO
Kemas
Wageeoo
Salawatty
Batchian
CELEBES
Peling
Xulla
Oby
NEW GUINEA
Mysol I.
Ceram
Booro
Amboina
Banda
Booton
Volcano
Seroa
Nila
P. Dama
Roma
Wetter
Panter
FLORIS
Volcano
Volcano
Solor
Lomblem
Ombay
TIMOR
Comobe
Wood I.

Island, in the Loo Choo archipelago, emits sulphureous vapour; and Formosa suffers greatly from earthquakes. In Luzon, the most northern and largest of the Philippines, are three active volcanos; Mindinao also was in eruption in 1764. The line is then prolonged through Sanguir and the north-eastern extremity of Celebes, by Ternate and Tidore, to the Moluccas, and, amongst the rest, Sumbawa. Here a great transverse line may be said to run from east to west. On the west it passes through the whole of Java, where there are thirty-eight large volcanic mountains, many of which continually discharge smoke and sulphureous vapours. In the volcanos of Sumatra, the same linear arrangement is preserved; but the line inclines gradually to the north-west in such a manner as to point to the active volcano in Barren Island, in the Bay of Bengal, in about the twelfth degree of north latitude. In another direction the volcanic range is prolonged through Borneo, Celebes, Banda, and New Guinea; and farther eastward in New Britain, New Ireland, and various parts of the Polynesian archipelago. The Pacific Ocean, indeed, seems, in equatorial latitudes, to be one vast theatre of igneous action; and its innumerable archipelagos, such as the New Hebrides, Friendly Islands, and Georgian Isles, are all composed either of coralline limestones, or volcanic rocks with active vents here and there interspersed. The abundant production of carbonate of lime, in solution, would alone raise a strong presumption of the volcanic constitution of these tracts, even if there were not more positive proofs of igneous agency.

Volcanic region from the Caspian to the Azores.—If we now turn our attention to the principal region in the Old World, which, from time immemorial, has been agitated by earthquakes, and has given vent, at certain points, to subterranean fires, we find that it possesses the same general characters. This region extends from east to west for the distance of about one thousand geographical miles, from the Caspian Sea to the Azores; including within its limits the greater part of the Mediterranean, and its most prominent peninsulas. From

south to north, it reaches from about the thirty-fifth to the forty-fifth degree of latitude. Its northern boundaries are Caucasus, the Black Sea, the mountains of Thrace, Transylvania, and Hungary,—the Austrian, Tyrolian, and Swiss Alps, —the Cevennes and Pyrenees, with the mountains which branch off from the Pyrenees westward, to the north side of the Tagus. Its western limits are the ocean, but it is impossible to determine how far it may be prolonged in that direction; neither can we assign with precision its extreme eastern limit, since the country beyond the Caspian and the Sea of Aral is scarcely known. The great steppe of Tartary, in particular, is unexplored; and we are almost equally ignorant of the physical constitution of China, in which country, however, many violent earthquakes have been felt.

The southern boundaries of the region include the most northern parts of Africa, and part of the Desert of Arabia *. We may trace, through the whole area comprehended within these extensive limits, numerous points of volcanic eruptions, hot springs, gaseous emanations, and other signs of igneous agency; while few tracts, of any extent, have been entirely exempt from earthquakes throughout the last three thousand years.

Borders of the Caspian.—To begin on the Asiatic side, we find that, on the western shores of the Caspian, in the country round Baku, there is a tract called the Field of Fire, which continually emits inflammable gas, and springs of naphtha and petroleum occur in the same vicinity, as also mud volcanos. In the chain of Elburs, to the south of this sea, is a lofty mountain, which, according to Morier, sometimes emits smoke, and at the base of which are several small craters, where sulphur and saltpetre are procured in sufficient abundance to be used in commerce. Violent subterranean commotions have been experienced along the borders of the Caspian; and it is reported that, since 1556, the waters of that sea have encroached on the Russian territory to the north; but the fact, as Malte-

* Hoff, vol. ii. p. 99.

Brun observes, requires confirmation. According to Engelhard and Parrot, the depth of the water has increased in places, while the general surface has been lowered ; and they say that the bottom of the sea has, in modern times, varied in form ; and that, near the south coast, the Isle of Idak, north from Astrabat, formerly high land, has now become very low *. Any indications of a change in the relative levels of the land in this part of Asia, are of more than ordinary interest, because a succession of similar variations would account for many prominent features in the physical geography of the district between the salt lake Aral, and the western shores of the Euxine—a district well known to have been always subject to great earthquakes.

Steppes of the Caspian.—The level of the Caspian is lower than that of the Black Sea, by about 300 feet. A low and level tract, called the Steppe, abounding in saline plants, and said to contain shells of species now common in the adjoining sea, skirts the shores of the Caspian, on the north-west. This plain often terminates abruptly by a line of inland cliffs, at the base of which runs a kind of beach, consisting of fragments of limestone and sand, cemented together into a conglomerate. Pallas has endeavoured to show that there is an old line of sandy country, which indicates the ancient bed of a strait, by which the Caspian sea was once united to that of Azof. On similar grounds, it is inferred that the salt lake Aral was formerly connected with the Caspian.

Tradition of deluges on the shores of the Bosphorus, &c.—However modern in the earth's history the convulsions may be which have produced the phenomena of the steppes, it is consistent with analogy to suppose that a very minute portion of the whole change has happened in the last twenty or thirty centuries. Yet, if we possessed more authentic records of physical events, we should probably discover that some small portion of those great revolutions have fallen within such recent periods. Remote traditions have come down to us of inunda-

* Travels in the Crimea and Caucasus, in 1815, vol. i. pp. 257 and 264.—Hoff, vol. i. p. 137.

tions, in which the waters of the Black Sea were forced through the Thracian Bosphorus, and through the Hellespont, into the Ægean. In the deluge of Samothrace, it appears that that small island, and the adjoining coast of Asia, were inundated; and in the Ogygian, which happened at a different time, Bœotia and Attica were overflowed. Notwithstanding the mixture of fable, and the love of the marvellous, in those rude ages, and the subsequent inventions of Greek poets and historians, it may be distinctly perceived that the floods alluded to were local and transient, and that they happened in succession near the borders of that chain of inland seas. They seem, therefore, to have been nothing more than great waves, which, about fifteen centuries before our era, devastated the borders of the Black Sea, the Sea of Marmora, the Archipelago and neighbouring coasts, in the same manner as the western shores of Portugal, Spain, and Northern Africa were inundated, during the great earthquake at Lisbon, by a wave which rose, in some places, to the height of fifty or sixty feet; or as happened in Peru, in 1746, where two hundred violent shocks followed each other in the space of twenty-four hours, and the ocean broke with impetuous force upon the land, destroying the town of Callao, and four other seaports, and converting a considerable tract of inhabited country into a bay.

In the country between the Caspian and the Black Seas, and in the chain of Caucasus, numerous earthquakes have, in modern times, caused fissures and subsidences of the soil, especially at Tiflis *. The Caucasian territories abound in hot-springs and mineral waters. So late as 1814, a new island was raised by volcanic explosions, in the Sea of Azof; and Pallas mentions that, in the same locality, opposite old Temruk, a submarine eruption took place in 1799, accompanied with dreadful thundering, emission of fire and smoke, and the throwing up of mire and stones. Violent earthquakes were felt at the same time at great distances from Temruk. The country around Erzerum exhibits similar phenomena, as does

* Hoff, vol. ii. p. 210.

that around Tauris and the lake of Urmia, in which latter we have already remarked the rapid formation of travertin. The lake of Urmia, which is about two hundred and eighty English miles in circumference, resembles the Dead Sea, in having no outlet, and in being more salt than the ocean. Between the Tigris and Euphrates, also, there are numerous springs of naphtha, and frequent earthquakes agitate the country.

Syria and Palestine abound in volcanic appearances, and very extensive areas have been shaken, at different periods, with great destruction of cities and loss of lives.

Periodical alternation of Earthquakes in Syria and Southern Italy.—It has been remarked by Von Hoff, that from the commencement of the thirteenth to the latter half of the seventeenth century, there was an almost entire cessation of earthquakes in Syria and Judea; and, during this interval of quiescence, the Archipelago, together with part of the adjacent coast of Lesser Asia, as also Southern Italy and Sicily, suffered extraordinary convulsions; while volcanic eruptions in those parts were unusually frequent. A more extended comparison, also, of the history of the subterranean convulsions of these tracts seems to confirm the opinion, that a violent crisis of commotion never visits both at the same time. It is impossible for us to declare, as yet, whether this phenomenon is constant in this, or general in other regions, because we can rarely trace back a connected series of events farther than a few centuries; but it is well known that, where numerous vents are clustered together within a small area, as in many archipelagos for instance, two of them are never in violent eruption at once. If the action of one becomes very great for a century or more, the others assume the appearance of spent volcanos. It is, therefore, not improbable that separate provinces of the same range of volcanic fires may hold a relation to one deep seated focus, analogous to that which the apertures of a small group bear to some one rent or cavity. Thus, for example, we may con-

jecture that, at a comparatively small distance from the surface, Ischia and Vesuvius mutually communicate with certain fissures, and that each affords relief alternately to elastic fluids and lava there generated. So we may suppose Southern Italy and Syria to be connected, at a much greater depth, with a lower part of the very same system of fissures; in which case any obstruction occurring in one duct may have the effect of causing almost all the vapour and melted matter to be forced up the other, and if they cannot get vent, they may be the cause of violent earthquakes.

Continual mention is made in history of the ravages committed by earthquakes in Sidon, Tyre, Berytus, Laodicea, and Antioch, as also in the island of Cyprus. The country around the Dead Sea appears evidently, from the accounts of modern travellers, to be volcanic; and there are similar appearances, according to Burckhardt, in Arabia Petrea. A district near Smyrna, in Asia Minor, was termed by the Greeks Catacecaumene, or the burnt, where there is a large arid territory, without trees, and with a cindery soil *.

Grecian Archipelago.—Proceeding westwards, we reach the Grecian Archipelago, where Santorin, afterwards to be described, is the grand centre of volcanic action. To the north-west of Santorin is another volcano, in the island of Milo, of recent aspect, having a very active solfatara in its central crater, and many sources of boiling water and steam. Continuing precisely the same line, we arrive at that part of the Morea, where we learn, from ancient writers, that Helice and Bura were, in the year 373 B. C., submerged beneath the sea by an earthquake; and the walls, according to Ovid, were to be seen beneath the waters. Near the same spot, in our times (1817), Vostizza was laid in ruins by a subterranean convulsion †. At Methone, also, (now Modon), in Messenia, about three centuries before our era, an eruption threw up a great volcanic mountain, which is represented by Strabo as being

* Strabo, Ed. Fal., p. 900.

† Hoff, vol. ii., p. 172.

nearly four thousand feet in height; but the magnitude of the hill requires confirmation. Some suppose that the accounts of the formation of a hill near Trœzene, of which the date is unknown, may refer to the same event. Macedonia, Thrace, and Epirus, have always been subject to earthquakes, and the Ionian Isles are continually convulsed. Respecting Southern Italy, Sicily, and the Lipari Isles, we need not enlarge here, as the existence of volcanos in that region is known to all, and we shall have occasion again to allude to them.

The north-eastern portion of Africa, including Egypt, which lies six or seven degrees south of the volcanic line already traced, has been almost always exempt from earthquakes; but the north-western portion, especially Fez and Morocco, which fall within the line, suffer greatly from time to time. The southern part of Spain, also, and Portugal, have generally been exposed to the same scourge simultaneously with Northern Africa. The provinces of Malaga, Murcia, and Grenada, and in Portugal, the country round Lisbon, are recorded at several periods to have been devastated by great earthquakes. It will be seen, from Michell's account of the great Lisbon shock in 1755, that the first movement proceeded from the bed of the ocean ten or fifteen leagues from the coast. So late as February 2, 1816, when Lisbon was vehemently shaken, two ships felt a shock in the ocean west from Lisbon; one of them at the distance of one hundred and twenty, and the other two hundred and sixty-two French leagues from the coast *—a fact which is the more interesting, because a line drawn through the Grecian archipelago, the volcanic region of Southern Italy, Sicily, Southern Spain, and Portugal, will, if prolonged westward through the ocean, strike the volcanic group of the Azores, which has, therefore, in all probability, a submarine connexion with the European line. How far the isles of Madeira and the Canaries, in the former of which

* Verneur, Journal des Voyages, vol. iv., p. 111. Hoff, vol. ii., p. 275.

violent earthquakes, and in the latter great eruptions, frequently happen, may communicate beneath the waters with the same region, must for the present be mere matter of conjecture.

Besides the continuous spaces of subterranean disturbance of which we have merely sketched the outline, there are other disconnected volcanic groups, of which the geographical extent is as yet very imperfectly known. Among these may be mentioned Iceland, which belongs, perhaps, to the same region as the volcano in Jan Mayen's Island, situated five degrees to the north-east. With these, also, part of the nearest coast of Greenland, which is sometimes shaken by earthquakes, may be connected. The island of Bourbon belongs to another theatre of volcanic action, of which Madagascar probably forms a part, if the alleged existence of burning volcanos in that island shall, on further examination, be substantiated. In following round the borders of the ocean to the north, we find the volcano of Gabel Tor, within the entrance of the Arabian Gulf. In the province of Cutch, and the adjoining districts of Hindostan, violent earthquakes repeatedly devastate an extensive territory.

Volcanic regions of Southern Europe.—Respecting the volcanic system of Southern Europe, it may be observed, that there is a central tract where the greatest earthquakes prevail, in which rocks are shattered, mountains rent, the surface elevated or depressed, and cities laid in ruins. On each side of this line of greatest commotion there are parallel bands of country, where the shocks are less violent. At a still greater distance (as in Northern Italy, for example, extending to the foot of the Alps), there are spaces where the shocks are much rarer and more feeble, yet possibly of sufficient force to cause, by continued repetition, some appreciable alteration in the external form of the earth's crust. Beyond these limits, again, all countries are liable to slight tremors at distant intervals of time, when some great crisis of subterranean movement agitates

an adjoining volcanic region; but these may be considered as mere vibrations, propagated mechanically through the external crust of the globe, as sounds travel almost to indefinite distances through the air. Shocks of this kind have been felt in England, Scotland, Northern France, and Germany—particularly during the Lisbon earthquake. But these countries cannot, on this account, be supposed to constitute parts of the southern volcanic region, any more than the Shetland and Orkney Isles can be considered as belonging to the Icelandic circle, because the sands ejected from Hecla have been wafted thither by the winds.

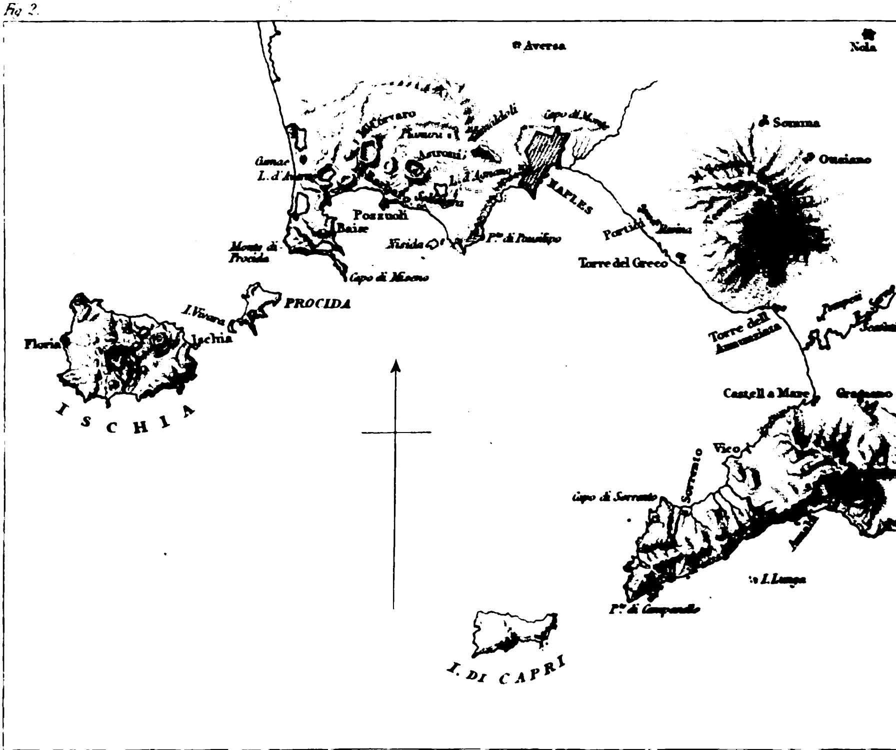
Lines of active and extinct Volcanos not to be confounded.—We must also be careful to distinguish between lines of extinct and active volcanos, even where they appear to run in the same direction; for ancient and modern systems may cross and interfere with each other. Already, indeed, we have proof that this is the case; so that it is not by geographical position, but by reference to the species of organic beings alone, whether aquatic or terrestrial, whose remains occur in beds interstratified with lavas, that we can clearly distinguish the relative age of volcanos of which no eruptions are recorded. Had Southern Italy been known to civilized nations for as short a period as America, we should have had no record of eruptions in Ischia; yet we might have assured ourselves that the lavas of that isle had flowed since the Mediterranean was inhabited by the species of testacea now living in the Neapolitan seas. With this assurance it would not have been rash to include the numerous vents of that isle in the modern volcanic group of Campania.

On similar grounds we may class, without much hesitation, the submarine lavas of the Val di Noto in Sicily, in the modern circle of subterranean commotion, of which Etna and Calabria form a part. But the lavas of the Euganean hills and the Vicentin, although not wholly beyond the range of earthquakes in Northern Italy, must not be confounded with any

existing volcanic system; for when they flowed, the seas were inhabited by animals almost all of them distinct from those now known to live, whether in the Mediterranean or other parts of the globe. But we cannot enter into a full development of our views on these subjects in the present volume, as they would carry us into the consideration of changes in the earth's surface far anterior to the times of history, to which our present examination is exclusively confined.

Island of Procida — Island of Ischia.
Part of the Coast of Misenum.

Fig 2.



CHAPTER XIX.

History of the volcanic eruptions in the district round Naples—Early convulsions in the island of Ischia—Numerous cones thrown up there—Epomeo not an habitual volcano—Lake Avernus—The Solfatara—Renewal of the eruptions of Vesuvius A.D. 79—Pliny's description of the phenomena—Remarks on his silence respecting the destruction of Herculaneum and Pompeii—Subsequent history of Vesuvius—Lava discharged in Ischia in 1302—Pause in the eruptions of Vesuvius—Monte Nuovo thrown up—Uniformity of the volcanic operations of Vesuvius and the Phlegræan Fields in ancient and modern times.

VOLCANIC DISTRICT OF NAPLES.

WE shall next present the reader with a sketch of the history of some of the volcanic vents dispersed throughout the great regions before described, and consider attentively the composition and arrangement of their lavas and ejected matter. The only volcanic region known to the ancients was that of which the Mediterranean forms a part; and they have transmitted to us very imperfect records of the eruptions in three principal provinces of that region, namely, the district round Naples, that of Sicily and its isles, and that of the Grecian Archipelago. By far the most connected series of records throughout a long period relates to the first of these districts; and these cannot be too attentively considered, as much historical information is indispensable in order to enable us to obtain a clear view of the connexion and alternate mode of action of the different vents in a single volcanic group.

Early convulsions in the island of Ischia.—The Neapolitan volcanos extend from Vesuvius, through the Phlegræan Fields, to Procida and Ischia, in a somewhat linear arrangement, ranging from the north-east to the south-west, as will be seen in the annexed map (Pl. 2). Within the space above limited, the volcanic force is sometimes developed in single eruptions from a considerable number of irregularly-scattered points;

but a great part of its action has been confined to one principal and habitual vent, Vesuvius or Somma. Before the Christian era, from the remotest periods of which we have any tradition, this principal vent was in a state of inactivity. Terrific convulsions then took place from time to time in Ischia (Pithecusa), and seem to have extended to the neighbouring isle of Procida (Prochyta), for Strabo* mentions a story of the latter having been torn asunder from Ischia; and Pliny † derives its name from its having been poured forth by an eruption from Ischia. So violent were the earthquakes and volcanic explosions to which Ischia was subject, that Typhon the giant, 'from whose eyes and mouth fire proceeded, and who hurled stones to heaven with a loud and hollow noise,' was said to lie buried beneath it.

The present circumference of the island along the water's edge is eighteen miles, its length from west to east about five, and its breadth from north to south three miles. Several Greek colonies which settled there before the Christian era were compelled to abandon it in consequence of the violence of the eruptions. First the Erythræans, and afterwards the Chalcidians, are mentioned as having been driven out by earthquakes and igneous exhalations. A colony was afterwards established by Hiero, king of Syracuse, about three hundred and eighty years before the Christian era; but when they had built a fortress, they were compelled by an eruption to fly, and never again returned. Strabo tells us that Timæus recorded a tradition, that, a little before his time, Epomeus, the principal mountain in the centre of the island, vomited fire during great earthquakes; that the land between it and the coast had ejected much fiery matter which flowed into the sea, and that the sea receded for the distance of three stadia, and then returning, overflowed the island. This eruption is supposed by some to have been that which formed the crater of Monte Corvo on one of the higher flanks of Epomeo, above Foria, the lava-

* Lib. v. † Nat. Hist., lib. iii., c. 6.

current of which may still be traced, by aid of the scoriæ on its surface, from the crater to the sea.

To one of the subsequent eruptions in the lower parts of the isle, which caused the expulsion of the first Greek colony, Monte Rotaro has been attributed, and it bears every mark of recent origin. The cone is remarkably perfect, and has a crater on its summit precisely resembling that of Monte Nuovo; but the hill is larger, and resembles some of the more considerable cones of single eruption near Clermont in Auvergne, and, like some of them, it has given vent to a lava-stream at its base, instead of its summit. A small ravine swept out by a torrent exposes the structure of the cone, which is composed of innumerable inclined and slightly undulating layers of pumice, scoriæ, white lapilli, and enormous angular blocks of trachyte. These last have evidently been thrown out by violent explosions, like those which in 1822 launched from Vesuvius a mass of pyroxenic lava, of many tons weight, to the distance of three miles, which fell in the garden of Prince Ottajano. The cone of Rotaro is covered with the arbutus, and other beautiful evergreens. Such is the strength of the virgin soil, that the shrubs have become almost arborescent; and the growth of some of the smaller wild plants has been so vigorous, that botanists have scarcely been able to recognize the species.

The eruption whereby the Syracusan colony was dislodged is supposed to have given rise to that mighty current which forms the promontory of Zaro and Caruso. The surface of these lavas is still very arid and bristling, and is covered with black scoriæ; so that it is not without great labour that human industry has redeemed some small spots, and converted them into vineyards. From the date of the great eruption last alluded to, down to our own time, Ischia has enjoyed tranquillity, with the exception of one emission of lava hereafter to be described, which, although it occasioned much local damage, does not appear to have devastated the whole country, in the manner of more ancient explosions.

Epomeo of submarine origin.—The population of the isle amounts at present to about twenty-five thousand, and is on the increase. They are supported almost entirely on the production of their vineyards. The lofty central hill, Epomeo or S. Nichola, on this island, is composed of greenish indurated tuff, of a prodigious thickness, interstratified in some parts with argillaceous marl, and, here and there, with great streams of indurated lava. Visconti ascertained, by trigonometrical measurement, that this mountain was 2605 feet above the level of the sea. In mineral composition and in form, as seen from many points of view, it resembles the hill to the north of Naples, on the summit of which stands the convent of Camaldoli, which is 1643 feet in height. Both these mountains, like the greater part of those in the Terra di Lavoro, are of subaqueous origin; although it has frequently happened to them, as to Epomeo, that, after being elevated above the level of the sea, fresh eruptions have broken through at different points. I found more than one argillaceous stratum, containing marine shells, within eight hundred feet of the summit of Epomeo; and from this circumstance, and from the general structure of the mountain, I am compelled to dissent from the opinion expressed by Mr. Scrope, who supposed it to have been once a great habitual volcano, like Vesuvius*. At least it is certain, that if any one of the cones on the present mountain gave vent to several streams of lava in succession, this happened when the whole mass was still beneath the level of the sea. Brocchi long ago announced, that the igneous rocks of this island rest on a plastic clay containing shells. Of these a considerable number have now been obtained, and identified with species still living in the Mediterranean.

Number of volcanic cones in Ischia.—There are, upon the whole, on different parts of Epomeo, or scattered through the lower tracts of the island, twelve considerable volcanic cones, which have been thrown up since the island was raised above the surface of the deep; and many streams of lava may have

* Geol. Trans., vol. ii. part iii. p. 388; second series.

flowed, like that of 'Arso' in 1302, without cones having been produced; so that this isle may, for ages before the period of the remotest traditions, have served as a safety-valve to the whole Terra di Lavoro, while the fires of Vesuvius were dormant.

Lake Avernus.—It seems also clear, that Avernus, a circular lake near Puzzuoli, about half a mile in diameter, which is now a salubrious and cheerful spot, once exhaled mephitic vapours, such as are often emitted by craters after eruptions. There is no reason for discrediting the account of Lucretius *, that birds could not fly over it without being stifled, although they may now frequent it uninjured. There must have been a time when this crater was in action; and for many centuries afterwards it may have deserved the appellation of 'atri janua Ditis,' emitting, perhaps, gases as destructive of animal life as those suffocating vapours which were given out by Lake Quilotoa, in Quito, in 1797, by which whole herds of cattle on its shores were killed †, or as those deleterious emanations which annihilated all the cattle in the island of Lancerote, one of the Canaries, in 1730 ‡. Bory St. Vincent mentions, that in the same isle birds fell lifeless to the ground; and Sir William Hamilton informs us that he picked up dead birds on Vesuvius during an eruption.

Solfatara.—The Solfatara, near Puzzuoli, which may be still considered as a half-extinguished crater, appears, by the accounts of Strabo and others, to have been before the Christian era in very much the same state as at present, giving vent continually to aqueous vapour, together with sulphureous and muriatic acid gases, similar to those evolved by Vesuvius.

Ancient history of Vesuvius.—Such, then, were the points where the subterranean fires obtained vent, from the earliest period to which tradition reaches back, down to the first cen-

* De Rerum Nat. VI., 740.—Mr. Forbes on the Bay of Naples, Edin. Journ. of Science, No. 3, *new series*, p. 87, Jan. 1830.

† Humboldt, Voy., p. 317.

‡ Von Buch, Ub. einen vulcanisch. Ausbruch auf der Insel Lanzerote.

tury of the Christian era; but we then arrive at a crisis in the volcanic action of this district—one of the most interesting events witnessed by man during the brief period throughout which he has observed the physical changes on the earth's surface. From the first colonization of Southern Italy by the Greeks, Vesuvius afforded no other indications of its volcanic character than such as the naturalist might infer, from the analogy of its structure to other volcanos. These were recognized by Strabo, but Pliny did not include the mountain in his list of active vents. The ancient cone was of a very regular form, terminating, not as at present, in two peaks, but with a flattish summit, where the remains of an ancient crater, nearly filled up, had left a slight depression, covered in its interior by wild vines, and with a sterile plain at the bottom. On the exterior, the flanks of the mountain were covered with fertile fields richly cultivated, and at its base were the populous cities of Herculaneum and Pompeii. But the scene of repose was at length doomed to cease, and the volcanic fire was recalled to the main channel, which, at some former unknown period, had given passage to repeated streams of melted lava, sand, and scoriæ.

Renewal of its eruptions.—The first symptom of the revival of the energies of this volcano was the occurrence of an earthquake in the year 63 after Christ, which did considerable injury to the cities in its vicinity. From that time to the year 79 slight shocks were frequent, and in the month of August of that year they became more numerous and violent, till they ended at length in an eruption. The elder Pliny, who commanded the Roman fleet, was then stationed at Misenum; and in his anxiety to obtain a near view of the phenomena, he lost his life, being suffocated by sulphureous vapours. His nephew, the younger Pliny, remained at Misenum, and has given us, in his Letters, a lively description of the awful scene. A dense column of vapour was first seen rising vertically from Vesuvius, and then spreading itself out laterally, so that its upper portion resembled the head, and its lower the trunk of the pine, which

characterizes the Italian landscape. This black cloud was pierced occasionally by flashes of fire as vivid as lightning, succeeded by darkness more profound than night. Ashes fell even upon the ships at Misenum, and caused a shoal in one part of the sea—the ground rocked, and the sea receded from the shores, so that many marine animals were seen on the dry sand. The appearances above described agree perfectly with those witnessed in more recent eruptions, especially those of Monte Nuovo in 1538, and of Vesuvius in 1822.

Silence of Pliny respecting the destruction of Herculaneum and Pompeii.—In all times and countries, indeed, there is a striking uniformity in the volcanic phenomena; but it is most singular that Pliny, although giving a circumstantial detail of so many physical facts, and enlarging upon the manner of his uncle's death, and the ashes which fell when he was at Stabiæ, makes no allusion whatever to the sudden overwhelming of two large and populous cities, Herculaneum and Pompeii. All naturalists who have searched into the memorials of the past, for records of physical events, must have been surprised at the indifference with which the most memorable occurrences are often passed by, in the works of writers of enlightened periods; as also of the extraordinary exaggeration which usually displays itself in the traditions of similar events, in ignorant and superstitious ages. But, of all omissions, the most inexplicable, perhaps, is that now under consideration; and we have no hesitation in saying, that had the buried cities never been discovered, the accounts transmitted to us of their tragical end would have been discredited by the majority, so vague and general are the narratives, or so long subsequent to the event. Tacitus, the friend and contemporary of Pliny, when adverting in general terms to the convulsion, says merely that 'cities were consumed or buried *.'

Suetonius, although he alludes to the eruption incidentally, is silent as to the cities. They are mentioned by Martial, in an epigram, as immersed in cinders; but the first historian who

* Haustæ aut obrutæ urbes.—Hist., lib. i.

alludes to them by name is Dion Cassius *, who flourished about a century and a half after Pliny. He appears to have derived his information from the traditions of the inhabitants, and to have recorded, without discrimination, all the facts and fables which he could collect. He tells us, 'that during the eruption, a multitude of men of superhuman stature, resembling giants, appeared sometimes on the mountain and sometimes in the environs—that stones and smoke were thrown out, the sun was hidden, and then the giants seemed to rise again, while the sounds of trumpets were heard, &c. &c.; and finally,' he relates, 'two entire cities, Herculaneum and Pompeii, were buried under showers of ashes, while all the people were sitting in the theatre.' That many of these circumstances were invented, would have been obvious, even without the aid of Pliny's Letters; and the examination of Herculaneum and Pompeii enables us to prove, that none of the people were destroyed in the theatres, and, indeed, that there were very few of the inhabitants who did not escape from both cities. Yet some lives were lost, and there was ample foundation for the tale in its most essential particulars.

This case may often serve as a caution to the geologist, who has frequent occasion to weigh, in like manner, negative evidence derived from the silence of eminent writers, against the obscure but positive testimony of popular traditions. Some authors, for example, would have us call in question the reality of the Ogygian deluge, because Homer and Hesiod say nothing of it. But they were poets, not historians, and they lived many centuries after the latest date assigned to the catastrophe. Had they even lived at the time of that flood, we might still contend that their silence ought, no more than Pliny's, to avail against the authority of tradition, however much exaggeration we may impute to the latter.

It does not appear that in the year 79 any lava flowed from Vesuvius; the ejected substances, perhaps, consisted entirely of lapilli, sand, and fragments of older lava, as when Monte

* Hist. Rom., lib. lxvi.

Nuovo was thrown up in 1538. The first era at which we have authentic accounts of the flowing of a stream of lava, is the year 1036, which is the seventh eruption from the revival of the fires of the volcano. A few years afterwards, in 1049, another eruption is mentioned, and another in 1138 (or 1139), after which a great pause ensued of one hundred and sixty-eight years. During this long interval of repose, two minor vents opened at distant points. In the first place it is on tradition that an eruption took place from the Solfatara in the year 1198, during the reign of Frederic II., Emperor of Germany; and although no circumstantial detail of the event has reached us from those dark ages, we may receive the fact without hesitation *. Nothing more, however, can be attributed to this eruption, as Mr. Scrope observes, than the discharge of a light and scoriform trachytic lava, of recent aspect, resting upon the strata of loose tufa which covers the principal mass of trachyte †.

Volcanic eruption in Ischia, 1302.—The other occurrence is well authenticated,—the eruption, in the year 1302, of a lava-stream, from a new vent on the south-east side of the Island of Ischia. During part of 1301, earthquakes had succeeded one another with fearful rapidity; and they terminated at last with the discharge of a lava-stream from a point named the Campo del Arso, not far from the town of Ischia. This lava ran quite down to the sea—a distance of about two miles: in colour it varies from iron grey to reddish black, and is remarkable for the glassy felspars which it contains. Its surface is almost as sterile, after a period of five centuries, as if it had cooled down yesterday. A few scantlings of wild thyme, and two or three other dwarfish plants, alone appear in the interstices of the scoriæ, while the Vesuvian lava of 1767 is already covered with a luxuriant vegetation. Pontanus, whose country-house was burnt and overwhelmed, describes the dreadful scene as having

* The earliest authority, says Mr. Forbes, given for this fact, appears to be Capaccio, quoted in the Terra Tremante of Bonito.—Edin. Journ. of Sci., &c. No. I., new series, p. 127, July, 1829.

† Geol. Trans., vol. ii. part iii. p. 346, second series.

lasted two months *. Many houses were swallowed up, and a partial emigration of the inhabitants followed. This eruption produced no cone, but only a slight depression, hardly deserving the name of a crater, where heaps of black and red scoriæ lie scattered around. Until this eruption, Ischia is generally believed to have enjoyed an interval of rest for about seventeen centuries; but Julius Obsequens †, who flourished A.D. 214, refers to some volcanic convulsion in the year 662, after the building of Rome. (91 B.C.) As Pliny, who lived a century before Obsequens, does not enumerate this among other volcanic eruptions, the statement of the latter author is supposed to have been erroneous; but it would be more consistent, for reasons before stated, to disregard the silence of Pliny, and to conclude that some kind of subterranean commotion, probably of no great violence, happened at the period alluded to.

Subsequent history of Vesuvius.—To return to Vesuvius,—the next eruption occurred in 1306; between which era and 1631 there was only one other (in 1500), and that a slight one. It has been remarked, that throughout this period Etna was in a state of such unusual activity as to lend countenance to the idea that the great Sicilian volcano may sometimes serve as a channel of discharge to elastic fluids and lava that would otherwise rise to the vents in Campania.

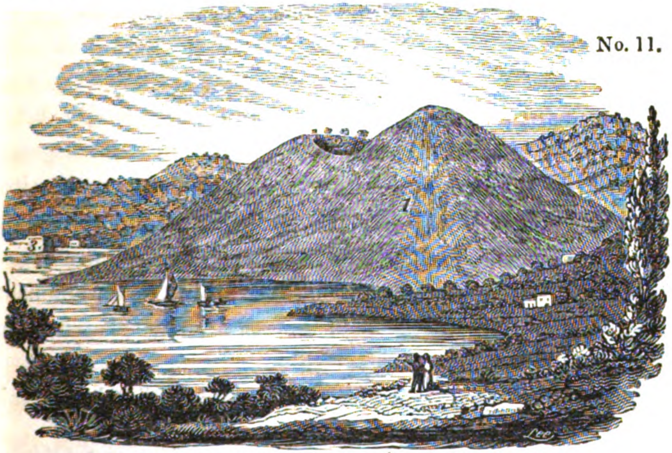
Formation of Monte Nuovo, 1538.—The great pause was also marked by a memorable event in the Phlegræan Fields—the sudden formation of a new mountain in 1538, of which we have received authentic accounts from contemporary writers. Frequent earthquakes, for two years preceding, disturbed the neighbourhood of Puzzuoli; but it was not until the 27th and 28th of September, 1538, that they became alarming, when not less than twenty shocks were experienced in twenty-four hours. At length, on the night of the 29th, two hours after sunset, a gulf opened between the little town of Tripergola, which once existed on the site of the Monte Nuovo, and the baths in its suburbs, which were much frequented. This

* Lib. vi., de Bello Neap. in Grævii Thesaur.

† Prodig. libell., c. cxiv.

watering place contained a hospital for those who resorted thither for the benefit of the thermal springs, and it appears that there were no fewer than three inns in the principal street. A large fissure approached the town with a tremendous noise, and began to discharge pumice-stones, blocks of unmelted lava and ashes mixed with water, and occasionally flames. The ashes fell in immense quantities, even at Naples; while the neighbouring Puzzuoli was deserted by its inhabitants. The sea retired suddenly for two hundred yards, and a portion of its bed was left dry. We shall afterwards, when treating of earthquakes, show by numerous proofs derived not only from the state of the Temple of Serapis (see Frontispiece), but from many other physical phenomena, that the whole coast, from Monte Nuovo to beyond Puzzuoli, was at that time upraised to the height of many feet above the bed of the Mediterranean, and has ever since remained permanently elevated. On the 3rd of October the eruption ceased, so that the hill (fig. 1, No. 11), the great mass of which was thrown up in a day and a night, was accessible; and those who ascended reported that they found a funnel-shaped crater on its summit. (Fig. 2, No. 11.)

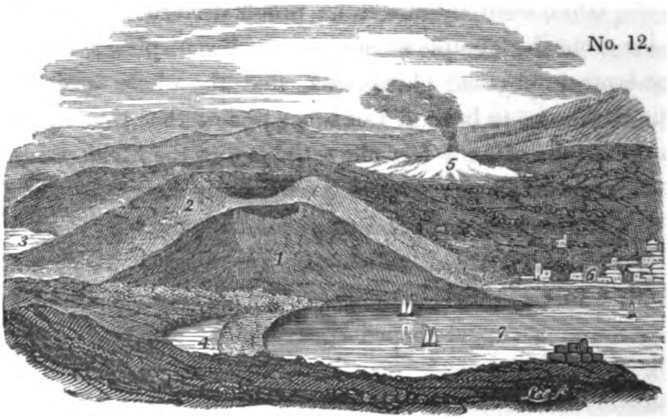
No. 11.



Monte Nuovo, formed in the Bay of Baiæ, Sept. 29th, 1538.

1. Cone of Monte Nuovo. 2. Brim of crater of ditto.
3. Thermal spring, called Baths of Nero, or Stufe di Tritoli.

The height of Monte Nuovo has recently been determined, by the Italian mineralogist Pini, to be four hundred and forty English feet above the level of the bay; its base is about eight thousand feet, or nearly a mile and a half, in circumference. According to Pini, the depth of the crater is four hundred and twenty-one English feet from the summit of the hill, so that its bottom is only nineteen feet above the level of the sea. No lava flowed from this cavity, but the ejected matter consisted of pumiceous scoriæ and masses of trachyte, many of them schistose, and resembling clinkstone. The Monte Nuovo is



The Phlegræan Fields.

1. Monte Nuovo. 2. Monte Barbaro.
3. Lake Avernus. 4. Lucrine Lake.
5. The Solfatara. 6. Puzzuoli.
7. Bay of Baiæ.

declared, by the best authorities, to stand partly on the site of the Lucrine lake (fig. 4, No. 12 *), which was nothing more than the crater of a pre-existent volcano, and was almost entirely filled during the explosion of 1538. Nothing now remains but a shallow pool, separated from the sea by an elevated beach, raised artificially.

Volcanos of the Phlegræan Fields.—Immediately adjoining

* This representation of the Phlegræan Fields is reduced from part of Plate xxxi. of Sir William Hamilton's great work, 'Campi Phlegræi,' to which we refer the reader for faithful delineations of the scenery of that country.

to Monte Nuovo is the larger volcanic cone of Monte Barbaro (fig. 2, No. 12), the Gaurus inanis of Juvenal—an appellation given to it probably from its deep circular crater, which is about a mile in diameter. Large as is this cone, it was probably produced by a single eruption; and it does not, perhaps, exceed in magnitude some of the largest of those in Ischia, which there is every reason to believe to have been formed within the historical era. It is composed chiefly of indurated tufa, like Monte Nuovo, stratified conformably to its conical surface. This hill was once very celebrated for its wines, and is still covered with vineyards; but when the vine is not in leaf it has a sterile appearance, and late in the year, when seen from the beautiful bay of Baiæ, it often contrasts so strongly in verdure with Monte Nuovo, which is always clothed with arbutus, myrtle, and other wild evergreens, that a stranger might well imagine the cone of older date to be that thrown up in the sixteenth century *.

There is nothing, indeed, so calculated to instruct the geologist as the striking manner in which the recent volcanic hills of Ischia, and that now under consideration, blend with the surrounding landscape. Nothing seems wanting or redundant; every part of the picture is in such perfect harmony with the rest, that the whole has the appearance of having been called into existence by a single effort of creative power. What other result could we have anticipated, if Nature has ever been governed by the same laws? Each new mountain thrown up—each new tract of land raised or depressed by earthquakes—should be in perfect accordance with those previously formed, if the entire configuration of the surface has been due to a long series of similar convulsions. Were it true that the greater part of the dry land originated simultaneously in its present state, and that additions were afterwards made slowly and successively; then, indeed, there might be reason to ex-

* Hamilton observes (writing in 1770), 'the new mountain produces as yet but a very slender vegetation.'—Campi Phlegræi, p. 69. This remark was not applicable in 1828.

pect a strong line of demarcation between the signs of ancient and modern changes. But the very continuity of the plan, and the perfect identity of the causes, are to many a source of deception, and lead them to exaggerate the energy of agents which operated in the earlier ages. In the absence of all historical information, they are as unable to separate the dates of the origin of different portions of our continents, as is the stranger to determine, by their physical features alone, the distinct ages of Monte Nuovo, Monte Barbaro, Astroni, and the Solfatara.

The vast scale and violence of the volcanic operations in Campania, in the olden time, has been a theme of declamation, and has been contrasted with the comparative state of quiescence of this delightful region in the modern era. Instead of inferring, from analogy, that the ancient Vesuvius was always at rest when the craters of the Phlegræan Fields were burning,—that each cone rose in succession,—and that many years, and often centuries, of repose intervened between each eruption—geologists seem to have generally conjectured that the whole group sprung up from the ground at once, like the soldiers of Cadmus when he sowed the dragon's teeth. As well might they endeavour to persuade us that on these Phlegræan Fields, as the poets feigned, the giants warred with Jove, ere yet the puny race of mortals were in being.

Modern Eruptions of Vesuvius.—For nearly a century after the birth of Monte Nuovo, Vesuvius still continued in a state of tranquillity. There had then been no violent eruption for four hundred and ninety-two years; and it appears that the crater was then exactly in the condition of the present extinct volcano of Astroni, near Naples. Bracini, who visited Vesuvius not long before the eruption of 1631, gives the following interesting description of the interior. 'The crater was five miles in circumference, and about a thousand paces deep; its sides were covered with brushwood, and at the bottom there was a plain on which cattle grazed. In the woody parts wild-boars frequently harboured. In one part of the plain, covered

with ashes, were three small pools, one filled with hot and bitter water, another salter than the sea, and a third hot but tasteless *.' But at length these forests and grassy plains were suddenly consumed—blown into the air, and their ashes scattered to the winds. In December, 1631, seven streams of lava poured at once from the crater, and overflowed several villages on the flanks and at the foot of the mountain. Resina, partly built over the ancient site of Herculaneum, was consumed by the fiery torrent. Great floods of mud were as destructive as the lava itself, as often happens during these catastrophes; for such is the violence of rains produced by the evolution of aqueous vapour, that torrents of water descend the cone, and, becoming charged with impalpable volcanic dust, roll along loose ashes, acquiring such consistency as to deserve their ordinary appellation of 'aqueous lavas.'

A brief period of repose ensued, which lasted only until the year 1666, from which time to the present there has been a constant series of eruptions, with rarely an interval of rest exceeding ten years. During these three centuries no irregular volcanic agency has convulsed other points in this district. Brieslak remarked that such irregular convulsions had occurred in the Bay of Naples, in every second century, as, for example, the eruption of the Solfatara in the twelfth, of the lava of Arso, in Ischia, in the fourteenth, and of Monte Nuovo in the sixteenth; but the eighteenth has formed an exception to this rule, and this seems accounted for by the unprecedented number of eruptions of Vesuvius during that period; whereas, when the new vents opened, there had always been, as we have seen, a long intermittance of activity in the principal volcano.

* Hamilton's Campi Phlegræi, folio, vol. i. p. 62; and Brieslak, Campanie, tome i. p. 186.

CHAPTER XX.

Volcanic District of Naples, *continued*—Dimensions and structure of the cone of Vesuvius—Dikes in the recent cone, how formed—Section though Vesuvius and Somma—Vesuvian lavas and minerals—Effects of decomposition on lavas—Alluvions called 'aqueous lavas'—Origin and composition of the matter enveloping Herculaneum and Pompeii—Controversies on the subject—Condition and contents of the buried cities—Proofs of their having suffered by an earthquake—Small number of skeletons—State of preservation of animal and vegetable substances—Rolls of Papyrus—Probability of future discoveries of MSS.—Stabiæ—Torre del Greco—Concluding remarks on the destroying and renovating agency of the Campanian volcanos.

VOLCANIC DISTRICT OF NAPLES, *continued.*

Structure of the cone of Vesuvius.—Between the end of the eighteenth century and the year 1822, the great crater of Vesuvius had been gradually filled by lava boiling up from below, and by scoriæ falling from the explosions of minor mouths which were formed at intervals on its bottom and sides. In place of a regular cavity, therefore, there was a rough and rocky plain, covered with blocks of lava and scoriæ, and cut by numerous fissures, from which clouds of vapour were evolved. But this state of things was totally changed by the eruption of October, 1822, when violent explosions, during the space of more than twenty days, broke up and threw out all this accumulated mass, so as to leave an immense gulph or chasm, of an irregular, but somewhat elliptical shape, about three miles in circumference when measured along the very sinuous and irregular line of its extreme margin, but somewhat less than three-quarters of a mile in its longest diameter, which was directed from N.E. to S.W.* The depth of this tremendous abyss has been variously estimated, for from the hour of its formation it decreased daily, by the dilapidation of its

* Account of the Eruption of Vesuvius in October, 1822, by G. P. Scrope, Esq., Journ. of Sci., &c., vol. xv. p. 175.

sides. It measured, at first, according to the account of some authors, two thousand feet in depth from the extreme part of the existing summit *; but Mr. Scrope, when he saw it, soon after the eruption, estimated its depth at less than half that quantity. More than eight hundred feet of the cone was carried away by the explosions, so that the mountain was reduced in height from about four thousand two hundred to three thousand four hundred feet †.

As we ascend the sloping sides, the volcano appears a mass of loose materials—a mere heap of rubbish, thrown together without the slightest order; but on arriving at the brim of the crater, and obtaining a view of the interior, we are agreeably surprised to discover that the conformation of the whole displays in every part the most perfect symmetry and arrangement. The materials are disposed in regular strata slightly undulating, appearing, when viewed in front, to be disposed in horizontal planes. But as we make the circuit of the edge of the crater, and observe the cliffs by which it is encircled projecting or receding in salient or retiring angles, we behold transverse sections of the currents of lava and beds of sand and scoriæ, and recognise their true dip. We then discover that they incline outwards from the axis of the cone, at angles varying from 30° to 45°. The whole cone, in fact, is composed of a number of concentric coatings of alternating lavas, sand, and scoriæ. Every shower of ashes which has fallen from above, and every stream of lava descending from the lips of the crater, have conformed to the outward surface of the hill, so that one conical envelope may be said to have been successively folded round another, until the aggregation of the whole mountain was completed. The marked separation into distinct beds results from the different colours and degrees of coarseness in the sands, scoriæ, and lava, and the alternation of these with each other. The greatest difficulty, on the first view, is to conceive how so much regularity can be produced, notwithstanding the unequal

* Mr. Forbes, Account of Mount Vesuvius, Edin. Journ. of Sci., No. xviii., p. 195, Oct., 1828. † Ibid., p. 194.

distribution of sand and scoriæ, driven by prevailing winds in particular eruptions, and the small breadth of each sheet of lava as it first flows out from the crater.

But on a closer examination we find that the appearance of extreme uniformity is delusive, for when a number of beds thin out gradually, and at different points, the eye does not without difficulty recognise the termination of any one stratum, but usually supposes it continuous with some other, which at a short distance may lie precisely in the same plane. The slight undulations, moreover, produced by inequalities on the sides of the hill on which the successive layers were moulded, assists the deception. As countless beds of sand and scoriæ constitute the greater part of the whole mass, these may sometimes mantle continuously round the whole cone; and even lava-streams may be of considerable breadth when first they overflow, since in some eruptions a considerable part of the upper portion of the cone breaks down at once, and may form a sheet extending as far as the space which the eye usually takes in in a single section.

The high inclination of some of the beds, and the firm union of the particles even where there is evidently no cement, is another striking feature in the volcanic tuffs and breccias, which seems at first not very easy of explanation. But the last great eruption afforded ample illustration of the manner in which these strata are formed. Fragments of lava, scoriæ, pumice, and sand, when they fall at slight distances from the summit, are only half cooled down from a state of fusion, and are afterwards acted upon by the heat from within, and by fumeroles or small crevices in the cone through which hot vapours are disengaged. Thus heated, the ejected fragments cohere together strongly; and the whole mass acquires such consistency in a few days, that fragments cannot be detached without a smart blow of the hammer. At the same time sand and scoriæ, ejected to a greater distance, remain incoherent *.

* Monticelli and Covelli, Storia di Fenon. del Vesuv., en 1821-2-3.

Dikes in the recent cone, how formed.—The inclined strata before mentioned, which dip outwards in all directions from the axis of the cone of Vesuvius, are intersected by veins or dikes of compact lava, for the most part in vertical position. In 1828 these were seen to be about seven in number, some of them not less than four or five hundred feet in height, and thinning out before they reached the uppermost part of the cone. Being harder than the beds through which they pass, they have resisted decomposition, and stand out in relief *.

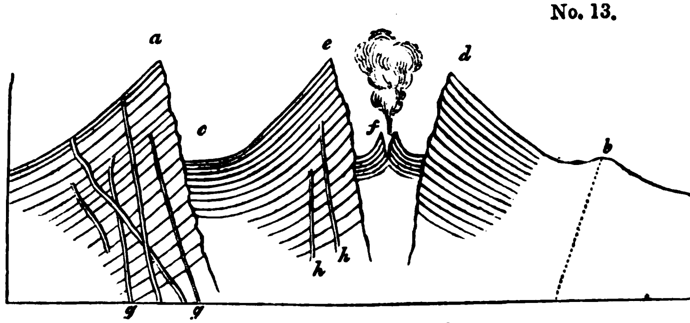
There can be no doubt that these dikes have been produced by the filling up of open fissures with liquid lava; but of the date of their formation we know nothing further than that they are all subsequent to the year 79, and, relatively speaking, that they are more modern than all the lavas and scoriæ which they intersect. A considerable number of the upper strata, not traversed by them, must have been due to later eruptions, if the dikes were filled from below. That the earthquakes which almost invariably precede eruptions occasion rents in the mass is well known; and, in 1822, three months before the lava flowed out, open fissures, evolving hot vapours, were numerous. It is clear that such rents must be injected with melted matter when the column of lava rises, so that the origin of the dikes is easily explained, as also the great solidity and crystalline nature of the rock composing

* When I visited Vesuvius in November, 1828, I was prevented from descending into the crater by the constant ejections then thrown out. I only got sight of three of the dikes, but Signor Monticelli had previously had drawings made of the whole, which he showed me. The veins which I saw were on that side of the cone which is encircled by Somma. In March of the year before mentioned, an eruption began at the bottom of the deep gulph formed in 1822. The ejected matter had filled up nearly one-third of the original abyss in November, and the same operation was slowly continuing, a single black cone being seen at the bottom in almost continual activity. It is clear that these ejections may continue till the throat of Vesuvius is filled up in the same manner as before 1822; and Mr. Scrope has referred the frequent occurrence of volcanic cones without craters to this cause. I found, in 1828, the lava of 1822 not yet cool on the north side of the cone, and evolving much heat and vapour from crevices.

them, which has been formed by lava cooling down slowly under great pressure.

Section through Vesuvius and Somma.—In the annexed diagram (No. 13) it will be seen that, on the side of Vesuvius opposite to that where a portion of the ancient cone of Somma (*a*) still remains, is a projection (*b*) called the Pedamentina, which some have supposed to be part of the circumference of

No. 13.



Supposed section of Vesuvius and Somma.

a. Monte Somma, or the remains of the ancient cone of Vesuvius.

b. The Pedamentina, a terrace-like projection, encircling the base of the recent cone of Vesuvius, on the south side.

c. Atrio del Cavallo *.

d. *e*. Crater left by eruption of 1822.

f. Small cone thrown up in 1828, at the bottom of the great crater.

g. *g*. Dikes intersecting Somma.

h. *h*. Dikes intersecting the recent cone of Vesuvius.

the ancient crater broken down towards the sea, and over the edge of which the lavas of the modern Vesuvius have poured; the axis of the present cone of Vesuvius being, according to Visconti, precisely equidistant from the escarpment of Somma and the Pedamentina. But it has been objected (and not without reason) to this hypothesis, that if the Pedamentina and the escarpment of Somma were the remains of the original *crater*, that crater must have been many miles in diameter, and more enormous than almost any one known on the globe. It

* So called from travellers leaving their horses and mules there when they prepare to ascend the cone on foot.

is therefore more probable that the ancient mountain was higher than Vesuvius (which, comparatively speaking, is a volcano of no great height), and that the explosions of the year 79 caused it not merely to disgorge the contents of its crater, which had long been choked up, but blew up a great part of the cone itself: so that the wall of Somma, and the ridge or terrace of the Pedamentina, were never the margin of a crater of eruption, but are the relics of a ruined and truncated cone. It will be seen in the diagram that the slanting beds of the cone of Vesuvius become horizontal in the Atrio del Cavallo (at *c*), where the base of the new cone meets the precipitous escarpment of Somma; for when the lava flows down to this point, as happened in 1822, its descending course is arrested, and it then runs in another direction along this small valley, circling round the base of the cone. Sand and scoriæ, also, blown by the winds, collect at the base of the cone, and are then swept away by torrents; so that there is always here a flattish plain, as represented. In the same manner the small interior cone (*f*) must be composed of sloping beds, terminating in a horizontal plain; for while this monticule was gradually gaining height by successive ejections of lava and scoriæ, in 1828, it was always surrounded by a flat pool of semi-fluid lava, into which scoriæ and sand were thrown.

The escarpment of Somma exhibits a structure precisely similar to that of the cone of Vesuvius, but the beds are intersected by a much greater number of dikes. The formation of this older cone does not belong to the historical era, and we must not therefore enlarge upon it in this place; but we shall have occasion presently to revert to the subject, when we speak of a favourite doctrine of some modern geologists, concerning 'craters of elevation' (Erhebung's Cratere), whereby, in defiance of analogy, the origin of the identical disposition of the strata and dikes in Vesuvius and Somma has been referred to a mode of operation totally dissimilar.

Vesuvian Lavas.—The modern lavas of Vesuvius are cha-

racterized by a large proportion of augite (or pyroxene). When they are composed of this mineral and felspar, they may be said to differ in no way in composition from many of the ancient volcanic rocks of Scotland. They are often porphyritic, containing disseminated crystals of augite, leucite, or some other mineral, imbedded in a more earthy base. These porphyritic lavas are often extremely compact, especially in the dikes of Vesuvius and Somma, which, in hardness and specific gravity, are by no means inferior to ordinary veins of trap, and, like them, often preserve a remarkable parallelism in their two opposite faces for considerable distances.

In regard to the structure of the Vesuvian lavas on a great scale, there are no sections of sufficient depth to enable us to draw fair comparisons between them and the products of extinct volcanos. At the fortress near Torre del Greco a section is exposed, fifteen feet in height, of a current which ran into the sea; and it evinces, especially in the ower part, a decided tendency to divide into rude columns. A still more striking example may be seen to the west of Torre del Annunziata, near Forte Scassato, where the mass is laid open by the sea to the depth of twenty feet. In both these cases, however, the rock may rather be said to be divided into numerous perpendicular fissures, than to be prismatic, although the same picturesque effect is produced. In the lava-currents of Central France (those of the Vivarais, in particular), the uppermost portion, often forty feet or more in thickness, is an amorphous mass passing downwards into lava, irregularly prismatic; and, under this, there is a foundation of regular and vertical columns, in that part of the current which must have cooled most slowly. But the lavas last mentioned are often one hundred feet or more in thickness; and we cannot expect to discover the same phenomenon in the shallow currents of Vesuvius, although it may be looked for in modern streams in Iceland, which exceed even those of ancient France in volume. Mr. Scrope * mentions that, in the cliffs encircling the great

* Journ. of Sci., vol. xv. p. 177.

crater of the modern cone, he saw many currents offering a columnar division, and some almost as regularly prismatic as any ranges of the older basalts; and he adds, that in some the spheroidal concretionary structure, on a large scale, was equally conspicuous. Brieslak * also informs us that, in the siliceous lava of 1737, which contains augite, leucite, and crystals of felspar, he found very regular prisms in a quarry near Torre del Greco; which observation is confirmed by modern authorities †.

Effects of decomposition on lavas.—The decomposition of some of the felspathic lavas, either by simple weathering, or by gaseous emanations, converts them from a hard to a soft clayey state, so that they no longer retain the smallest resemblance to rocks cooled down from a state of fusion. The exhalations of sulphuretted hydrogen and muriatic acid which are disengaged continually from the Solfatara, also produce curious changes on the trachyte of that extinct volcano: the rock is whitened and becomes porous, fissile, and honeycombed, till at length it crumbles into a white siliceous powder ‡. Numerous globular concretions, composed of concentric laminæ, are also formed by the same vapours in this decomposed rock §.

They who have visited the Phlegræan Fields and the volcanic region of Sicily, and who are aware of the many problematical appearances which igneous rocks of the most modern origin assume, especially after decomposition, cannot but be astonished at the confidence with which the contending Neptunists and Vulcanists in the last century dogmatized on the igneous or aqueous origin of certain rocks of the remotest antiquity. Instead of having laboured to acquire an accurate acquaintance with the aspect of known volcanic rocks, and the transmutations which they undergo subsequently to their first

* Voy. dans la Campanie, tome i. p. 201.

† Mr. Forbes on Mount Vesuvius, Edin. Journ. of Sci., No. xviii., Oct. 1828.

‡ Daubeny on Volcanos, p. 169.

§ Scrope, Geol. Trans., second series, vol. ii. p. 346.

consolidation, the adherents of both parties seem either to have considered themselves born with an intuitive knowledge of the effects of volcanic operations, or to have assumed that they required no other analogies than those which a laboratory and furnace might supply.

Vesuvian Minerals.—A great variety of minerals are found in the lavas of Vesuvius and Somma; for there are so many common to both, that it is unnecessary to separate them. Augite, leucite, felspar, mica, olivine, and sulphur, are most abundant. It is an extraordinary fact, that, in an area of three square miles round Vesuvius, a greater number of simple minerals have been found than in any spot of the same dimensions on the surface of the globe. Häuy only enumerated three hundred and eighty species of simple minerals as known to him, and no less than eighty-two had been found on Vesuvius before the end of the year 1828 *. Many of these are peculiar to that locality. Some mineralogists have conjectured that the greater part of these were not of Vesuvian origin, but thrown up in fragments from some older formation, through which the gaseous explosions burst. But none of the older rocks in Italy, or elsewhere, contain such an assemblage of mineral products; and the hypothesis seems to have been prompted by a disinclination to admit that, in times so recent in the earth's history, the laboratory of Nature could have been so prolific in the creation of new and rare compounds. Had Vesuvius been a volcano of high antiquity, formed when Nature

> Wanton'd as in her prime, and play'd at will
> Her virgin fancies,

it would have been readily admitted that these, or a much greater variety of substances, had been sublimed in the crevices of lava, just as several new earthy and metallic compounds are known to have been produced by fumeroles, since the eruption of 1822. But some violent hypothesis must always be resorted to, in order to explain away facts which imply the unimpaired energy of reproductive causes, in our own times.

* Monticelli and Covelli, Prodrom. della Mineral. Vesuv.

Formation of Tuffs.—We have hitherto described the structure of the cone; but a small part only of the ejected matter remains so near to the volcanic orifice. A large portion of sand and scoriæ is borne by the winds and scattered over the surrounding plains, or falls into the sea; and much more is swept down by torrents into the deep, during the intervals, often protracted for many centuries, between eruptions. There, horizontal deposits of tufaceous matter become intermixed with sediments of other kinds, and with shells and corals, and, when afterwards raised, form rocks of a mixed character, such as tuffs, peperinos, and volcanic conglomerates.

Flowing of lava under water.—Some of the lavas, also, of Vesuvius reach the sea, as do those of almost all volcanos; since they are generally in islands, or bordering the coast. Here they find a bottom already rendered nearly level, for reasons before explained by us when speaking of deltas. Instead, therefore, of being highly inclined, as around the cone, or in narrow bands as in a valley, they spread out in broad horizontal sheets so long as they retain their fluidity; and this process may probably continue for a considerable time, since, as upon the land, the upper coating of hardened lava protects the liquid and moving mass below from contact with the air, so beneath the sea the same superficial crust may prevent the great body of lava from cooling, and, being pressed upon by the weight of an increasing column of water as the current descends, it is probably squeezed down: thus the subjacent matter, still in a state of fusion, may be made to flow rapidly towards all points of the compass.

Volcanic alluvions.—In addition to the ejections which fall on the cone, and that much greater mass which finds its way gradually to the neighbouring sea, there is a third portion often of no inconsiderable thickness, composed of alluvions, spread over the valleys and plains at small distances from the volcano. Immense volumes of aqueous vapour are evolved from a crater during eruptions, and often for a long time subsequently to the discharge of scoriæ and lava. These vapours are condensed in

the cold atmosphere surrounding the high volcanic peak, and heavy rains are caused sometimes even in countries where, under other circumstances, such a phenomenon is entirely unknown. The floods thus occasioned sweep along the impalpable dust and light scoriæ, till a current of mud is produced, which is called, in Campania, 'lava d'acqua,' and is often more dreaded than an igneous stream (lava di fuoco), from the greater velocity with which it moves. So late as the 27th of October, 1822, one of these alluvions descended the cone of Vesuvius. After overspreading much cultivated soil, it flowed suddenly into the villages of St. Sebastian and Massa, and, filling the streets and interior of some of the houses, suffocated seven persons. It will therefore happen very frequently, that, towards the base of a volcanic cone, alternations will be found of lava, alluvions, and showers of ashes.

Mass enveloping Herculaneum and Pompeii. To which of these two latter divisions the mass enveloping Herculaneum and Pompeii should be referred, has been a question of the keenest controversy; but the discussion might have been shortened, if the combatants had reflected that, whether volcanic sand and ashes were conveyed to the towns by running water, or through the air, during an eruption, the interior of buildings, so long as the roofs remain entire, together with all underground vaults and cellars, could only be filled by an *alluvion*. We learn from history, that a heavy shower of sand, pumice, and lapilli, sufficiently great to render Pompeii and Herculaneum uninhabitable, fell for eight successive days and nights, in the year 79, accompanied by violent rains. We ought, therefore, to find a very close resemblance between the strata covering these towns, and those composing the minor cones of the Phlegræan Fields, accumulated rapidly, like Monte Nuovo, during a continued shower of ejected matter; with this difference, that the strata incumbent on the cities would be horizontal, whereas those in the cones are highly inclined, and that large angular fragments of rock, which are thrown out near the vent, would be wanting at a distance, where small lapilli only would be found. Accord-

ingly, with these exceptions, no identity can be more perfect than the form and distribution of the matter at the base of Monte Nuovo, as laid open by the encroaching sea, and the appearance of the beds superimposed on Pompeii. That city is covered with numerous alternations of different horizontal beds of tuff and lapilli, for the most part thin, and subdivided into very fine layers. I observed the following section near the Amphitheatre, in November, 1828—(descending series).

	Feet.	Inches.
1. Black sparkling sand from the eruption of 1822, containing minute regularly-formed crystals of augite and tourmaline from		2 to 3*
2. Vegetable mould	3	0
3. Brown incoherent tuff full of *pisolitic globules* in layers, from half an inch to three inches in thickness . .	1	6
4. Small scoriæ and white lapilli	0	3
5. Brown earthy tuff with numerous pisolitic globules .	0	9
6. Brown earthy tuff with lapilli divided into layers . .	4	0
7. Layer of whitish lapilli	0	1
8. Grey solid tuff	0	3
9. Pumice and white lapilli	0	3
	10	4

Many of the ashes in these beds are vitrified and harsh to the touch. Crystals of leucite, both fresh and farinaceous, have been found intermixed †. The depth of the bed of ashes above the houses is variable, but seldom exceeds twelve our fourteen feet, and it is said that the higher part of the Amphitheatre always projected above the surface; though, if this were the case, it seems to be inexplicable that the city should never have been discovered till the year 1750. It will be observed, in the above section, that two of the brown half-consolidated tuffs are filled with small pisolitic globules. It is surprising that this

* The last great eruption, in 1822, only caused a covering of a few inches thick on Pompeii. Several feet are mentioned by Mr. Forbes.—Ed. Journ. of Science, No. xix. p. 131, Jan. 1829. But he must have measured in spots where it had drifted. The dust and ashes were five feet thick at the top of the crater, and decreased gradually to ten inches at Torre del Annunziata. The size and weight of the ejected fragments diminished very regularly in the same continuous stratum as the distance from the centre of projection was greater.

† Forbes, Ed. Journ. of Sci., No. xix. p. 130, Jan. 1829.

circumstance is not alluded to in the animated controversy which the Royal Academy of Naples maintained with one of their members, Signor Lippi, as to the origin of the strata incumbent on Pompeii. The mode of aggregation of these globules has been fully explained by Mr. Scrope, who saw them formed in great numbers, in 1822, by rain falling during the eruption on fine volcanic sand, and sometimes, also, beheld them produced like hail in the air, by the mutual attraction of the minutest particles of fine damp sand. Their occurrence, therefore, agrees remarkably well with the account of heavy rain, and showers of sand and ashes, recorded in history, and is opposed to the theory of an alluvion brought from a distance by a flood of water.

Controversy as to the destruction of Herculaneum and Pompeii.—Lippi entitled his work 'Fu il fuoco o l' acqua che sotterró Pompei ed Ercolano * ?' and he contended that neither were the two cities destroyed in the year 79, nor by a volcanic eruption, but purely by the agency of water charged with transported matter. His Letters, wherein he endeavoured to dispense, as far as possible, with igneous agency, even at the foot of the volcano, were dedicated, with great propriety, to Werner, and afford an amusing illustration of the polemic style in which geological writers of that day indulged themselves. His arguments were partly of an historical nature, derived from the silence of contemporary historians, respecting the fate of the cities which, as we have already stated, is most remarkable; and were partly drawn from physical proofs. He pointed out with great clearness the resemblance of the tufaceous matter in the vaults and cellars at Herculaneum and Pompeii to aqueous alluvions, and its distinctness from ejections which had fallen through the air. Nothing, he observed, but moist pasty matter could have received the impression of a woman's breast, which was found in a vault at Pompeii, or have given the cast of a statue discovered in the theatre at Herculaneum. It was objected to him, that the heat of the tuff in Herculaneum and

* Napoli, 1816.

Pompeii was proved by the carbonization of the timber, corn, papyrus-rolls, and other vegetable substances there discovered: but Lippi replied with truth, that the papyri would have been burnt up, if they had come in contact with fire, and that their being only carbonized, was a clear demonstration of their having been enveloped, like fossil wood, in a sediment deposited from water. The Academicians, in their report on his pamphlet, assert, that when the Amphitheatre was first cleared out, the matter was arranged, on the steps, in a succession of concave layers, accommodating themselves to the interior form of the building, just as snow would lie if it had fallen there. This observation is highly interesting, and points to the difference between the stratification of ashes in an open building, and of mud derived from the same in the interior of edifices and cellars. Nor ought we to call the allegation in question, because it could not be substantiated at the time of the controversy, when the matter was all removed; although Lippi took advantage of this removal, and met the argument of his antagonists by requiring them to prove the fact.

Pompeii not destroyed by lava.—There is decisive evidence that no stream of lava has ever reached Pompeii since it was first built, although the foundations of the town stand upon the old leucitic lava of Somma; several of whose streams, with tuff interposed, have been cut through in excavations. At Herculaneum the case is different, although the substance which fills the interior of the houses and the vaults must have been introduced in a state of mud, like that found in similar situations in Pompeii: yet the superincumbent mass differs wholly in composition and thickness. Herculaneum was situated several miles nearer to the volcano, and has, therefore, been always more exposed to be covered, not only by showers of ashes, but by alluvions and streams of lava. Accordingly, masses of both have accumulated on each other above the city, to a depth of nowhere less than seventy, and in many places of one hundred and twelve feet *.

* Hamilton's Observations on Mount Vesuvius, p. 94. London, 1774.

The tuff which envelops the buildings consists of comminuted volcanic ashes, mixed with pumice. A mask imbedded in this matrix has left a cast, the sharpness of which was compared by Hamilton to those in Paris plaster; nor was the mask in the least degree scorched, as we might expect it to have been, if it had been imbedded in heated matter. This tuff is porous, and, when first excavated, is soft and easily worked, but acquires a considerable degree of induration on exposure to the air. Above this lowest stratum is placed, according to Hamilton, 'the matter of six eruptions,' each separated from the other by veins of good soil. In these soils Lippi informs us, that he collected a considerable number of land shells—an observation which is no doubt correct, for we know that in Italy several species burrow annually, in certain seasons, to the depth of five feet and more from the surface. Della Torre also informs us that there is in one part of this superimposed mass a bed of true siliceous lava (*lava di pietra dura*); and, as no such current is believed to have flowed till near one thousand years after the destruction of Herculaneum, we must conclude, that the origin of a large part of the covering of Herculaneum was long subsequent to the first inhumation of the place. That city, as well as Pompeii, was a seaport. Herculaneum is still very near the shore, but a tract of land, a mile in length, intervenes between the borders of the Bay of Naples and Pompeii. In both cases the gain of land is due to the filling up of the bed of the sea with volcanic matter, and not to elevation by earthquakes, for there has been no change in the relative level of land and sea. Pompeii stood on a slight eminence composed of the lavas of the ancient Vesuvius, and flights of steps led down to the water's edge. The lowermost of these steps are said to be still on an exact level with the sea.

Condition and contents of the buried cities.—After these observations on the nature of the strata enveloping and surrounding the cities, we may proceed to consider their internal condition and contents, so far at least as they offer facts of

geological interest. Notwithstanding the much greater depth at which Herculaneum was buried, it was discovered before Pompeii, by the accidental circumstance of a well being sunk, in 1713, which came right down upon the theatre, where the statues of Hercules and Cleopatra were soon found. Whether this city or Pompeii, both of them founded by Greek colonies, was the most considerable, is not yet determined; but both are mentioned by ancient authors as among the seven most flourishing cities in Campania. The walls of Pompeii were three miles in circumference; but we have, as yet, no certain knowledge of the dimensions of Herculaneum. In the latter place the theatre alone is open for inspection; the Forum, Temple of Jupiter, and other buildings, having been filled up with rubbish as the workmen proceeded, owing to the difficulty of removing it from so great a depth below ground. Even the theatre is only seen by torch-light, and the most interesting information, perhaps, which the geologist obtains there, is the continual formation of stalactite in the galleries cut through the tuff; for there is a constant percolation of water charged with carbonate of lime mixed with a small portion of magnesia. Such mineral waters must, in the course of time, create great changes in many rocks: and we cannot but perceive the unreasonableness of the expectations of some geologists, that volcanic rocks of remote eras should accord precisely with those of modern date; since it is obvious that many of those produced in our own time will not long retain the same aspect and composition.

Both at Herculaneum and Pompeii, temples have been found with inscriptions commemorating their having been rebuilt after they were thrown down by an earthquake *. This earthquake happened in the reign of Nero, sixteen years before the inhumation of the cities. In Pompeii, one-fourth of which is now laid open to the day, both the public and private buildings bear testimony to the catastrophe. The walls are rent, and in many places traversed by fissures still open.

* Swinburne and Lalande—Paderni, Phil. Trans. 1758, vol. 50, p. 619.

Columns are lying on the ground only half hewn from huge blocks of travertin, and the temple for which they were designed is seen half repaired. In some few places the pavement had sunk in, but in general it was undisturbed, consisting of great flags of lava, in which two immense ruts have been worn by the constant passage of carriages through the narrow street. When the hardness of the stone is considered, the continuity of these ruts from one end of the town to the other is not a little remarkable, for there is nothing of the kind in the oldest pavements of modern cities.

Small number of skeletons.—A very small number of skeletons have been discovered in either city; and it is clear that the great mass of inhabitants not only found time to escape, but also to carry with them the principal part of their valuable effects. In the barracks at Pompeii were the skeletons of two soldiers chained to the stocks, and in the vaults of a country-house in the suburbs, were the skeletons of seventeen persons who appear to have fled there to escape from the shower of ashes. They were found inclosed in an indurated tuff, and in this matrix was preserved a perfect cast of a woman, perhaps the mistress of the house, with an infant in her arms. Although her form was imprinted on the rock, nothing but the bones remained. To these a chain of gold was suspended, and rings with jewels were on the fingers of the skeleton. Against the sides of the same vault was ranged a long line of earthen amphoræ.

The writings scribbled by the soldiers on the walls of their barracks, and the names of the owners of each house written over the doors, are still perfectly legible. The colours of fresco paintings on the stuccoed walls in the interior of buildings are almost as vivid as if they were just finished. There are public fountains decorated with shells laid out in patterns in the same fashion as those now seen in the town of Naples; and in the room of a painter who was perhaps a naturalist, a large collection of shells was found comprising a great variety of Mediterranean species, in as good a state of preservation as if they

had remained for the same number of years in a museum. A comparison of these remains with those found so generally in a fossil state would not assist us in obtaining the least insight into the time required to produce a certain degree of decomposition or mineralization; for although, under favourable circumstances, much greater alteration might doubtless have been brought about in a shorter period, yet the example before us shows that an inhumation of seventeen centuries may sometimes effect nothing towards the reduction of shells and several other bodies to the state in which fossils are usually found.

The wooden beams in the houses at Herculaneum are black on the exterior, but when cleft open they appear to be almost in the state of ordinary wood, and the progress made by the whole mass towards the state of lignite is scarcely appreciable. Some animal and vegetable substances of more perishable kinds have of course suffered much change and decay, yet the state of conservation of these is truly remarkable. Fishing-nets are very abundant in both cities, often quite entire; and their number at Pompeii is the more interesting from the sea being now, as we stated, a mile distant. Linen has been found at Herculaneum, with the texture well defined; and in a fruiterer's shop in that city were discovered vessels full of almonds, chestnuts, walnuts, and fruit of the 'carubiere,' all distinctly recognizable from their shape. A loaf, also, still retaining its form, was found in a baker's shop, with his name stamped upon it thus: 'Eleris Q. Crani Riser.' On the counter of an apothecary was a box of pills converted into a fine earthy substance; and by the side of it a small cylindrical roll, evidently prepared to be cut into pills. By the side of these was a jar containing medicinal herbs. In 1827, moist olives were found in a square glass case, and 'caviare,' or roe of a fish, in a state of wonderful preservation. An examination of these curious condiments has been published by Covelli, of Naples, and they are preserved hermetically sealed in the museum there *.

* Mr. Forbes, Edin. Journ. of Sci., No. xix. p. 130, Jan., 1829.

Papyri.—There is a marked difference in the condition and appearance of the animal and vegetable substances found in Pompeii and Herculaneum; those of Pompeii being penetrated by a gray pulverulent tuff, those in Herculaneum seeming to have been first enveloped by a paste which consolidated round them, and then allowed them to become slowly carbonized. Some of the rolls of papyrus at Pompeii still retain their form; but the writing, and indeed almost all the vegetable matter, appear to have vanished and to have been replaced by volcanic tufa somewhat pulverulent. At Herculaneum the earthy matter has scarcely ever penetrated; and the vegetable substance of the papyrus has become a thin friable black matter, almost resembling in appearance the tinder which remains when stiff paper has been burnt, in which the letters may still be sometimes traced. The small bundles of papyri, composed of five or six rolls tied up together, had sometimes lain horizontally, and were pressed in that direction, but sometimes they had been placed in a vertical position. Small tickets were attached to each bundle, on which the title of the work was inscribed. In one case only have the sheets been found with writing on both sides of the pages. So numerous are the obliterations and corrections, that many must have been original manuscripts. The variety of hand-writings is quite extraordinary: almost all are written in Greek, but there are a few in Latin. They were all found in the library of one private individual; and the titles of four hundred of those least injured, which have been read, are found to be unimportant works, but all entirely new, chiefly relating to music, rhetoric, and cookery. There are two volumes of Epicurus 'On Nature,' and the others are mostly by writers of the same school, only one fragment having been discovered, by an opponent of the Epicurean system, Crisippus*.

* In one of the manuscripts which was in the hands of the interpreters when I visited the museum, the author indulges in the speculation that all the Homeric personages were allegorical—that Agamemnon was the ether, Achilles the sun, Helen the earth, Paris the air, Hector the moon, &c.

In the opinion of some antiquaries, not one-hundredth part of the city has yet been explored; and the quarters hitherto cleared out, at great expense, are those where there was the least probability of discovering manuscripts.

Probability of future discoveries of MSS.—As Italy could already boast splendid Roman amphitheatres and Greek temples, it was a matter of secondary interest to add to their number those in the dark and dripping galleries of Herculaneum; and having so many of the masterpieces of ancient art, we could have dispensed with the inferior busts and statues which could alone have been expected to reward our researches in the ruins of a provincial town. But from the moment that it was ascertained that rolls of papyrus preserved in this city could still be decyphered, every exertion ought to have been steadily and exclusively directed towards the discovery of other libraries. *Private dwellings* should have been searched, and no labour and expense should have been consumed in examining public edifices. A small portion of that zeal and enlightened spirit which prompted the late French and Tuscan expedition to Egypt, might, long ere this, in a country nearer home, have snatched from oblivion some of the lost works of the Augustan age, or of most of the eminent Greek historians and philosophers. A single roll of papyrus might have disclosed more matter of intense interest than all that was ever written in hieroglyphics *.

Stabiæ.—Besides the cities already mentioned, Stabiæ, a small town about six miles from Vesuvius, and near the site of the modern Castel-a-Mare (see map, plate 2), was overwhelmed during the eruption of 79. Pliny mentions that,

* During my stay at Naples, in 1828, the Neapolitan Government, after having discontinued operations for many years, cleared out a small portion of Herculaneum, near the sea, where the covering was least thick. After this expense had been incurred, it was discovered that the whole of the ground had been previously examined, near a century before, by the French Prince d'Elbeuf, who had removed everything of value! The want of system with which operations have always been, and still are, carried on is such, that we may expect similar blunders to be made continually.

when his uncle was there, he was obliged to make his escape, so great was the quantity of falling stones and ashes. In the ruins of this place, a few skeletons have been found buried in volcanic ejections, together with some antiquities of no great value, and rolls of papyrus, which, like those of Pompeii, were illegible.

Torre del Greco overflowed by lava.—Of the towns hitherto mentioned, Herculaneum alone has been overflowed by a stream of melted matter; but this did not, as we have seen, enter or injure the buildings which were previously enveloped or covered over with tuff. But burning torrents have often taken their course through the streets of Torre del Greco, and consumed or inclosed a large portion of the town in solid rock. It seems probable that the destruction of three thousand of its inhabitants, in 1631, which some accounts attribute to boiling water, was principally due to one of those alluvions which we before mentioned; but, in 1737, the lava itself flowed through the eastern side of the town, and afterwards reached the sea: and, in 1794, another current rolling over the western side, filled the streets and houses, and killed more than four hundred persons. The main street is now quarried through this lava, which supplied building-stones for new houses erected where others had been annihilated. The church was half buried in a rocky mass, but the upper portion served as the foundation of a new edifice.

The number of the population at present is estimated at fifteen thousand; and a satisfactory answer may readily be returned to those who inquire how the inhabitants can be so 'inattentive to the voice of time and the warnings of Nature*,' as to rebuild their dwellings on a spot so often devastated. No neighbouring site unoccupied by a town, or which would not be equally insecure, combines the same advantages of proximity to the capital, to the sea, and to the rich lands on the flanks of Vesuvius. If the present population were exiled, they would

* Sir H. Davy, Consolations in Travel, p. 66.

immediately be replaced by another, for the same reason that the Maremma of Tuscany and the Campagna di Roma will never be depopulated, although the malaria fever commits more havoc in a few years than the Vesuvian lavas in as many centuries. The district around Naples supplies one, amongst innumerable examples, that those regions where the surface is most frequently renewed, and where the renovation is accompanied, at different intervals of time, by partial destruction of animal and vegetable life, may nevertheless be amongst the most habitable and delightful on our globe.

We have already made a similar remark when speaking of tracts where aqueous causes are now most active; and the observation applies as well to parts of the surface which are the abode of aquatic animals, as to those which support terrestrial species. The sloping sides of Vesuvius give nourishment to a vigorous and healthy population of about eighty thousand souls; and the surrounding hills and plains, together with several of the adjoining isles, owe the fertility of their soil to matter ejected by prior eruptions. Had the fundamental limestone of the Apennines remained uncovered throughout the whole area, the country could not have sustained a twentieth part of its present inhabitants. This will be apparent to every geologist who has marked the change in the agricultural character of the soil the moment he has passed the utmost boundary of the volcanic ejections, as when, for example, at the distance of about seven miles from Vesuvius, he leaves the plain and ascends the declivity of the Sorrentine Hills.

Concluding remarks on the destroying and renovating agency of the Campanian volcanos.—Yet favoured as this region has been by Nature from time immemorial, the signs of the changes imprinted on it during the period that it has served as the habitation of man, may appear in after-ages to indicate a series of unparalleled disasters. Let us suppose that at some future time the Mediterranean should form a gulf of the great ocean, and that the tidal current should encroach on the shores of Campania, as it now advances upon the eastern coast of Eng-

land: the geologist will then behold the towns already buried, and many more which will evidently be entombed hereafter, laid open in the steep cliffs, where he will discover buildings superimposed above each other, with thick intervening strata of tuff or lava—some unscathed by fire, like those of Herculaneum and Pompeii, others half melted down, as in Torre del Greco, and many shattered and thrown about in strange confusion, as in Tripergola. Among the ruins will be seen skeletons of men, and impressions of the human form stamped in solid rocks of tuff. Nor will the signs of earthquakes be wanting. The pavement of part of the Domitian Way, and the Temple of the Nymphs, submerged at high tide, will be uncovered at low water, the columns remaining erect and uninjured. Other temples which had once sunk down, like that of Serapis, will be found to have been upraised again by subsequent movements. If they who study these phenomena, and speculate on their causes, assume that there were periods when the laws of Nature differed from those established in their own time, they will scarcely hesitate to refer the wonderful monuments in question to those primeval ages. When they consider the numerous proofs of reiterated catastrophes to which the region was subject, they may, perhaps, commiserate the unhappy fate of beings condemned to inhabit a planet during its nascent and chaotic state, and feel grateful that their favoured race escaped such scenes of anarchy and misrule.

Yet what was the real condition of Campania during those years of dire convulsion? 'A climate where heaven's breath smells sweet and wooingly—a vigorous and luxuriant nature unparalleled in its productions—a coast which was once the fairy land of poets, and the favourite retreat of great men. Even the tyrants of the creation loved this alluring region, spared it, adorned it, lived in it, died in it *.' The inhabitants, indeed, have enjoyed no immunity from the calamities which are the lot of mankind; but the principal evils which they have suffered must be attributed to moral, not to phy-

* Forsyth's Italy, vol. ii.

sical causes—to disastrous events over which man might have exercised a control, rather than to the inevitable catastrophes which result from subterranean agency. When Spartacus encamped his army of ten thousand gladiators in the old extinct crater of Vesuvius, the volcano was more justly a subject of terror to Campania, than it has ever been since the rekindling of its fires.

CHAPTER XXI.

External physiognomy of Etna—Minor cones produced by lateral eruptions—Successive obliteration of these cones—Early eruptions of Etna—Monti Rossi thrown up in 1669—Great fissure of S. Lio—Towns overflowed by lava.—Part of Catania destroyed—Mode of the advance of a current of lava—Excavation of a church under lava—Series of subterranean caverns—Linear direction of cones formed in 1811 and 1819—Flood produced in 1755 by the melting of snow during an eruption—A glacier covered by a lava-stream on Etna—Volcanic eruptions in Iceland—New island thrown up in 1783—Two lava currents of Skaptár Jokul in the same year—Their immense volume—Eruption of Jorullo in Mexico—Humboldt's Theory respecting the convexity of the Plain of Malpais.

ETNA.

External physiognomy of the cone.—As we have entered into a detailed historical account of the changes in the volcanic district round Naples, our limits will only permit us to allude in a cursory manner to some of the circumstances of principal interest in the history of other volcanic mountains. After Vesuvius, our most authentic records relate to Etna, which rises near the sea in solitary grandeur to the height of nearly eleven thousand feet *, the mass being chiefly composed of volcanic matter ejected above the surface of the water. The base of the cone is almost circular, and eighty-seven English miles in circumference; but if we include the whole district over which its lavas extend, the circuit is probably twice that extent.

Divided into three regions.—The cone is divided by Nature into three distinct zones, called the *fertile*, the *woody*, and the *desert* regions. The first of these, comprising the delightful country around the skirts of the mountain, is well cultivated, thickly inhabited, and covered with olives, vines, corn, fruit-trees, and aromatic herbs. Higher up, the woody region

* According to Captain Smyth (Sicily and its Islands, p. 145), its height is 10,874 feet.

encircles the mountain—an extensive forest, six or seven miles in width, affording pasturage for numerous flocks. The trees are of various species, the chestnut, oak, and pine being most luxuriant; while, in some tracts, are groves of cork and beech. Above the forest is the desert region, a waste of black lava and scoriæ; where, on a kind of plain, rises the cone to the height of about eleven hundred feet, from which sulphureous vapours are continually evolved. The most grand and original feature in the physiognomy of Etna is the multitude of minor cones which are distributed over its flanks, and which are most abundant in the woody region. These, although they appear but trifling irregularities when viewed from a distance as subordinate parts of so imposing and colossal a mountain, would, nevertheless, be deemed hills of considerable altitude in almost any other region.

Cones produced by lateral eruptions.—Without enumerating numerous monticules of ashes thrown out at different points, there are about eighty of these secondary volcanos, of considerable dimensions; fifty-two on the west and north, and twenty-seven on the east side of Etna. One of the largest, called Monte Minardo, near Bronte, is upwards of seven hundred feet in height; and a double hill near Nicolosi, called Monti Rossi, formed in 1669, is four hundred and fifty feet high, and the base two miles in circumference; so that it somewhat exceeds in size Monte Nuovo, before described. Yet it ranks only as a cone of the second magnitude amongst those produced by the lateral eruptions of Etna. On looking down from the lower borders of the desert region, these volcanos present us with one of the most beautiful and characteristic scenes in Europe. They afford every variety of height and size, and are arranged in beautiful and picturesque groups. However uniform they may appear when seen from the sea, or the plains below, nothing can be more diversified than their shape when we look from above into their craters, one side of which is generally broken down. There are, indeed, few objects in Nature more picturesque than a wooded vol-

canic crater. The cones situated in the higher parts of the forest zone are chiefly clothed with lofty pines; while those at a lower elevation are adorned with chestnuts, oak, beech, and holm.

Successive obliteration of these cones.—The history of the eruptions of Etna, imperfect and interrupted as it is, affords, nevertheless, a full insight into the manner in which the whole mountain has successively attained its present magnitude and internal structure. The principal cone has more than once fallen in and been reproduced. In 1444 it was three hundred and twenty feet high, and fell in after the earthquakes of 1537. In the year 1693, when a violent earthquake shook the whole of Sicily, and killed sixty thousand persons, the cone lost so much of its height, says Boccone, that it could not be seen from several places in Valdemone, whence it was before visible. The greater number of eruptions happen either from the great crater, or from lateral openings in the desert region. When hills are thrown up in the middle zone, and project beyond the general level, they gradually lose their height during subsequent eruptions; for when lava runs down from the upper parts of the mountain, and encounters any of these hills, the stream is divided, and flows round them so as to elevate the gently-sloping grounds from which they rise. In this manner a deduction is often made at once of twenty or thirty feet, or even more, from their height. Thus, one of the minor cones, called Monte Peluso, was diminished in altitude by a great lava-stream which encircled it in 1444; and another current has recently taken the same course—yet this hill still remains four or five hundred feet high.

There is a cone called Monte Nucilla, near Nicolosi, round the base of which several successive currents have flowed, and showers of ashes have fallen, since the time of history, till at last, during an eruption in 1536, the surrounding plain was so raised, that the top of the cone alone was left projecting above the general level. Monte Nero, situated above the Grotta dell' Capre, was in 1766 almost submerged by a cur-

rent; and Monte Capreolo afforded, in the year 1669, a curious example of one of the last stages of obliteration: for a lava-stream, descending on a high ridge which had been built up by the continued superposition of successive lavas, flowed directly into the crater, and nearly filled it. The lava, therefore, of each new lateral cone tends to detract from the relative height of lower cones above their base: so that the flanks of Etna, sloping with a gentle inclination, envelop in succession a great multitude of minor volcanos, while new ones spring up from time to time; and this has given to the older parts of the mountain, as seen in some sections two or three thousand feet perpendicular, a complex and highly interesting internal structure.

Early eruptions of Etna.—Etna appears to have been in activity from the earliest times of tradition; for Diodorus Siculus mentions an eruption which caused a district to be deserted by the Sicani before the Trojan war. Thucydides informs us*, that between the colonization of Sicily by the Greeks, and the commencement of the Peloponnesian war in the year 431 B.C., three eruptions had occurred. The last of these happened in the year 427 B.C., and ravaged the environs of Catania; and was probably that so poetically described by Pindar in his first Pythian ode.

Eruption of 1669—*Monti Rossi formed.*—The great eruption which happened in the year 1669 is the first to which we shall call the reader's attention. An earthquake had levelled to the ground all the houses in Nicolosi, a town situated near the lower margin of the woody region, about twenty miles from the summit of Etna, and ten from the sea at Catania. Two gulphs then opened near that town, from whence sand and scoriæ were thrown up in such quantity, that, in the course of three or four months, a double cone was formed, called Monti Rossi, about four hundred and fifty feet high. But the most extraordinary phenomenon occurred at the commencement of the convulsion in the plain of S. Lio. A fissure six feet broad,

* Book iii., towards the end.

No. 14.

Minor cones on the flanks of Etna.

1. Monti Rossi, near Nicolosi, formed in 1669. 2. Vampeluso?*

and of unknown depth, opened with a loud crash, and ran in a somewhat tortuous course to within a mile of the summit of Etna. Its direction was from north to south, and its length twelve miles. It emitted a most vivid light. Five other parallel fissures of considerable length afterwards opened one after the other, and emitted smoke, and gave out bellowing sounds which were heard at the distance of forty miles. This case seems to present the geologist with an illustration of the manner in which those continuous dikes of vertical porphyry were formed which are seen to traverse some of the older lavas of Etna; for the light emitted from the great rent of S. Lio appears to indicate that it was filled to a certain height with incandescent lava, probably to the height of an orifice not far distant from Monti Rossi, which at that time opened and poured out a lava current. The lava current to which we allude soon reached in its course a minor cone called Mompiliere, at the base of which it entered a subterranean grotto, communicating with a suite of those caverns which are so common in the lavas of Etna. Here it appears to have melted down some of the vaulted foundations of the hill, so that the

* The hill which I have here introduced was called by my guide Vampolara, but the name given in the text is the nearest to this which I find in Gemmellaro's Catalogue of Minor Cones.

whole of that cone became slightly depressed and traversed by numerous open fissures.

Part of Catania destroyed.—The lava, after overflowing fourteen towns and villages, some having a population of between three and four thousand inhabitants, arrived at length at the walls of Catania. hes e had been purposely raised to protect the city; but the burning flood accumulated till it rose to the top of the rampart, which was sixty feet in height, and then it fell in a fiery cascade and overwhelmed part of the city. The wall, however, was not thrown down, but was discovered long afterwards by excavations made in the rock by the Prince of Biscari; so that the traveller may now see the solid lava curling over the top of the rampart as if still in the very act of falling.

This great current had performed a course of fifteen miles before it entered the sea, where it was still six hundred yards broad and forty feet deep. It covered some territories in the environs of Catania, which had never before been visited by the lavas of Etna. While moving on, its surface was in general a mass of solid rock; and its mode of advancing, as is usual with lava-streams, was by the occasional fissuring of the solid walls. A gentleman of Catania, named Pappalardo, desiring to secure the city from the approach of the threatening torrent, went out with a party of fifty men whom he had dressed in skins to protect them from the heat, and armed with iron crows and hooks. They broke open one of the solid walls which flanked the current near Belpasso, and immediately forth issued a rivulet of melted matter which took the direction of Paternò; but the inhabitants of that town, being alarmed for their safety, took up arms, and put a stop to farther operations*.

As another illustration of the solidity of the walls of an advancing lava-stream, we may mention an adventure related by Recupero, who, in 1766, had ascended a small hill formed of ancient volcanic matter, to behold the slow and gradual approach of a fiery current, two miles and a half broad; when suddenly two small threads of liquid matter issuing from a

* Ferrara, Descriz. dell' Etna, p. 108.

crevice detached themselves from the main stream, and ran rapidly towards the hill. He and his guide had just time to escape, when they saw the hill, which was fifty feet in height, surrounded, and in a quarter of an hour melted down into the burning mass, so as to flow on with it.

But it must not be supposed that this complete fusion of rocky matter coming in contact with lava is of universal, or even common occurrence. It probably happens when fresh portions of incandescent matter come successively in contact with fusible materials. In many of the dikes which intersect the tuffs and lavas of Etna, there is scarcely any perceptible alteration effected by heat on the edges of the horizontal beds, in contact with the vertical and more crystalline mass. On the site of Mompiliere, one of the towns overflowed in the great eruption above described, an excavation was made in 1704; and by immense labour the workmen reached, at the depth of thirty-five feet, the gate of the principal church, where there were three statues, held in high veneration. One of these, together with a bell, some money, and other articles, were extracted in a good state of preservation from beneath a great arch formed by the lava. It seems very extraordinary that any works of art, not encased with tuff, like those in Herculaneum, should have escaped fusion in hollow spaces left open in this lava-current, which was so hot at Catania eight years after it entered the town, that it was impossible to hold the hand in some of the crevices.

Subterranean caverns on Etna.—We mentioned the entrance of the lava-stream into a subterranean grotto, whereby the foundations of a hill were partially undermined. Such underground passages are among the most curious features on Etna, and appear to have been produced by the hardening of the lava, during the escape of great volumes of elastic fluids, which are often discharged for many days in succession, after the crisis of the eruption is over. Near Nicolosi, not far from Monti Rossi, one of these great openings may be seen, called the Fossa della Palomba, 625 feet in circumference at its mouth,

and seventy-eight deep. After reaching the bottom of this, we enter another dark cavity, and then others in succession, sometimes descending precipices by means of ladders. At length the vaults terminate in a great gallery ninety feet long, and from fifteen to fifty broad, beyond which there is still a passage, never yet explored; so that the extent of these caverns remains unknown *. The walls and roofs of these great vaults are composed of rough and bristling scoriæ, of the most fantastic forms.

Eruption of 1811.—We shall now proceed to offer some observations on the two last eruptions in 1811 and 1819. It appears, from the relation of Signor Gemmellaro, who witnessed the phenomena, that the great crater in 1811 testified, by its violent detonations, that the lava had ascended to near the summit of the mountain, by its central duct. A violent shock was then felt, and a stream broke out from the side of the cone, at no great distance from its apex. Shortly after this had ceased to flow, a second stream burst forth at another opening, considerably below the first; then a third still lower, and so on till seven different issues had been thus successively formed, all lying upon the same straight line. It has been supposed that this line was a perpendicular rent in the internal framework of the mountain, which rent was probably not produced at one shock, but prolonged successively downwards, by the lateral pressure and intense heat of the internal column of lava, as it subsided by gradual discharge through each vent †.

Eruption of 1819.—In 1819 three large mouths or caverns opened very near those which were formed in the eruptions of 1811, from which flames, red hot cinders, and sand, were thrown up with loud explosions. A few minutes afterwards another mouth opened below, from which flames and smoke issued; and finally a fifth, lower still, whence a torrent of lava flowed, which spread itself with great velocity over the valley

* Ferrara, Descriz. dell' Etna. Palermo, 1818. † Scrope on Volcanos, p. 153.

'del Bove.' This stream flowed two miles in the first twenty-four hours, and nearly as far in the succeeding day and night. The three original mouths at length united into one large crater, and sent forth lava, as did the four inferior apertures, so that an enormous torrent poured down the great valley 'del Bove.' When it arrived at a vast and almost perpendicular precipice, at the head of the valley of Calanna, it poured over in a cascade, and, being hardened in its descent, made an inconceivable crash as it was dashed against the bottom. So immense was the column of dust raised by the abrasion of the tufaceous hill over which the hardened mass descended, that the Catanians were in great alarm, supposing a new eruption to have burst out in the woody region, exceeding in violence that near the summit of Etna.

Mode of advance of the lava.—Of the cones thrown up during this eruption, not more than two are of sufficient magnitude to be numbered among those eighty which we before reckoned as adorning the flanks of Etna. The surface of the lava which deluged the valley 'del Bove' consists of rocky and *angular* blocks, tossed together in the utmost disorder. Nothing can be more rugged, or more unlike the smooth and even superficies which those who are unacquainted with volcanic countries may have pictured to themselves, in a mass of matter which had consolidated from a liquid state. Mr. Scrope observed this current in the year 1819, slowly progressing down a considerable slope, at the rate of about a yard an hour, nine months after its first emission. The lower stratum being arrested by the resistance of the ground, the upper or central part gradually protruded itself, and being unsupported fell down. This in its turn was covered by a mass of more liquid lava, which swelled over it from above. The current had all the appearance of a huge heap of rough and large cinders rolling over and over upon itself by the effect of an extremely slow propulsion from behind. The contraction of the crust as it solidified, and the friction of the scoriform cakes against one another, produced a crackling

sound. Within the crevices a dull red heat might be seen by night, and vapour issuing in considerable quantity was visible by day *.

Flood produced by the melting of snow by lava.—The erosive and transporting power of running water is rarely exerted on Etna with great force, the rain which falls being immediately imbibed by the porous lavas; so that, vast as is the extent of the mountain, it feeds only a few small rivulets, and these, even, are dry throughout the greater portion of the year. The enormous rounded boulders, therefore, of trachyte and basalt, a line of which can be traced from the sea, from near Giardini, by Mascali, and Zafarana, to the valley 'del Bove,' would offer a perplexing problem to the geologist, if history had not preserved the memorials of a tremendous flood which happened in this district in the year 1755. It appears that two streams of lava flowed in that year, on the second of March, from the highest crater: they were immediately precipitated upon an enormous mass of snow, which then covered the whole mountain, and was extremely deep near the summit. The sudden melting of this frozen mass, by a fiery torrent three miles in length, produced a frightful inundation, which devastated the sides of the mountain for eight miles in length, and afterwards covered the lower flanks of Etna, where they were less steep, together with the plains near the sea, with great deposits of sand, scoriæ, and blocks of lava.

Many absurd stories circulated in Sicily respecting this event, such as that the water was boiling, and that it was vomited from the highest crater; that it was as salt as the sea, and full of marine shells; but these were mere inventions, to which Recupero, although he relates them as tales of the mountaineers, seems to have attached rather too much importance. Floods of considerable violence have been sometimes produced on Etna, by the fall of heavy rains, aided, probably, by the melting of snow. By this cause alone, in 1761, sixty

* Scrope, on Volcanos, p. 102.

of the inhabitants of Acicatena were killed, and many of their houses swept away *.

Glacier covered by a lava stream.—A remarkable discovery has lately been made on Etna of a great mass of ice, preserved for many years, perhaps for centuries, from melting, by the singular accident of a current of red hot lava having flowed over it. The following are the facts in attestation of a phenomenon which must at first sight appear of so paradoxical a character. The extraordinary heat experienced in the South of Europe, during the summer and autumn of 1828, caused the supplies of snow and ice which had been preserved in the spring of that year, for the use of Catania and the adjoining parts of Sicily and the island of Malta, to fail entirely. Great distress was felt for the want of a commodity regarded in these countries as one of the necessaries of life rather than an article of luxury, and on the abundance of which in some large cities the salubrity of the water and the general health of the community is said in some degree to depend. The magistrates of Catania applied to Signor M. Gemmellaro, in the hope that his local knowledge of Etna might enable him to point out some crevice or natural grotto on the mountain, where drift snow was still preserved. Nor were they disappointed; for he had long suspected that a small mass of perennial ice at the foot of the highest cone was part of a large and continuous glacier covered by a lava current. Having procured a large body of workmen, he quarried into this ice, and proved the superposition of the lava for several hundred yards, so as completely to satisfy himself that nothing but the subsequent flowing of the lava over the ice could account for the position of the glacier. Unfortunately for the geologist, the ice was so extremely hard, and the excavation so expensive, that there is no probability of the operations being renewed.

On the first of December 1828, I visited this spot, which is on the south-east side of the cone, and not far above the Casa Inglese, but the fresh snow had already nearly filled up the

* Ferrara, Descriz. dell' Etna, p. 116.

new opening, so that it had only the appearance of the mouth of a grotto. I do not, however, question the accuracy of the conclusion of Signor Gemmellaro, who being well acquainted with all the appearances of drift snow in the fissures and cavities of Etna, had recognized, even before the late excavations, the peculiarity of the position of the ice in this locality. We may suppose, that at the commencement of the eruption, a deep mass of drift snow had been covered by volcanic sand showered down upon it before the descent of the lava. A dense stratum of this fine dust mixed with scoriæ is well known to be an excellent non-conductor of heat; and the shepherds in the higher regions of Etna are accustomed to provide water for their flocks during summer, by strewing a layer of volcanic sand a few inches thick over the snow, which effectually prevents the sun from penetrating.

Suppose the mass of snow to have been preserved from liquefaction until the lower part of the lava had consolidated, we may then readily conceive that a glacier thus protected at the height of ten thousand feet above the level of the sea, would endure as long as the snows of Mont Blanc, unless melted by volcanic heat from below. When I visited the great crater in the beginning of winter, (December 1st, 1828,) I found the crevices in the interior encrusted with thick ice, and in some cases hot vapours were streaming out between masses of ice and the rugged and steep walls of the crater.

After the discovery of Signor Gemmellaro, it would not be surprising to find in the cones of the Icelandic volcanos, which are covered for the most part with perpetual snow, repeated alternations of lava streams and glaciers.

Volcanic eruptions in Iceland.—With the exception of Etna and Vesuvius, the most complete chronological records of a series of eruptions are those of Iceland: for their history reaches as far back as the ninth century of our era; and, from the beginning of the twelfth century, there is clear evidence that, during the whole period, there has never been an interval of more than forty, and very rarely one of twenty years, with-

out either an eruption or a great earthquake. So intense is the energy of the volcanic action in this region, that some eruptions of Hecla have lasted six years without ceasing. Earthquakes have often shaken the whole island at once, causing great changes in the interior, such as the sinking down of hills, the rending of mountains, the desertion by rivers of their channels, and the appearance of new lakes *. New islands have often been thrown up near the coast, some of which still exist, while others have disappeared either by subsidences or the action of the waves.

In the interval between eruptions, innumerable hot springs afford vent to subterranean heat, and solfataras discharge copious streams of inflammable matter. The volcanos in different parts of this island are observed, like those of the Phlegræan Fields, to be in activity by turns, one vent often serving for a time as a safety-valve to the rest. Many cones are often thrown up in one eruption, and in this case they take a linear direction, running generally from north-east to south-west, from the north-eastern part of the island where the volcano Krabla lies, to the promontory Reykianas.

New island thrown up in 1783.—The convulsions of the year 1783 appear to have been more tremendous than any recorded in the modern annals of Iceland; and the original Danish narrative of the catastrophe, drawn up in great detail, has since been substantiated by several English travellers, particularly in regard to the prodigious extent of country laid waste, and the volume of lava produced †. About a month previous to

* Hoff, vol. ii. p. 393.

† The first narrative of the eruption was drawn up by Stephensen, then Chief Justice in Iceland, appointed Commissioner by the King of Denmark, for estimating the damage done to the country, that relief might be afforded to the sufferers. Henderson was enabled to correct some of the measurements given by Stephensen, of the depth, width, and length of the lava currents, by reference to the MS. of Mr. Paulson, who visited the tract in 1794, and examined the lava with attention. (Journal of a Residence in Iceland, &c., p. 229.) Some of the principal facts are also corroborated by Dr. Hooker in his 'Tour in Iceland,' vol. ii., p. 128.

the eruption on the main land, a submarine volcano burst forth in the sea at the distance of thirty or forty miles in a south-west direction from Cape Reykianas, and ejected so much pumice, that the ocean was covered to the distance of one hundred and fifty miles, and ships were considerably impeded in their course. A new island was thrown up, consisting of high cliffs, within which, fire, smoke, and pumice were emitted from two or three different points. This island was claimed by his Danish Majesty, who denominated it Nyöe, or the new island; but, ere a year had elapsed, the sea resumed her ancient domain, and nothing was left but a rocky reef from five to thirty fathoms under water.

Great eruption of Skaptár Jokul.—Earthquakes, which had long been felt in Iceland, became violent on the 11th of June, when Skaptár Jokul, distant nearly two hundred miles from Nyöe, threw out a torrent of lava which flowed down into the river Skaptâ, and completely dried it up. The channel of the river was between high rocks, in many places from four hundred to six hundred feet in depth, and near two hundred in breadth. Not only did the lava fill up these great defiles to the brink, but it overflowed the adjacent fields to a considerable extent. The burning flood, on issuing from the confined rocky gorge, was then arrested for some time by a deep lake, which formerly existed in the course of the river between Skaptardal and Aa, which it entirely filled. The current then proceeded again, and reaching some ancient lava full of subterraneous caverns, penetrated and melted down part of it; and in some places where the steam could not gain vent, it blew up the rock, throwing fragments to the height of more than one hundred and fifty feet. On the 18th of June, another ejection of liquid lava rushed from the volcano, which flowed down with amazing velocity over the surface of the first stream. By the damming up of the mouths of some of the tributaries of the Skaptâ, many villages were completely overflowed with water, and thus great destruction of property was

caused. The lava, after flowing for several days, was precipitated down a tremendous cataract called Stapafoss, where it filled a profound abyss, which that great waterfall had been hollowing out for ages, and then the fiery current continued its course.

On the 3rd of August, fresh floods of lava still pouring from the volcano, a new branch was sent off in a different direction; for the channel of the Skaptâ was now so entirely choked up, and every opening to the west and north so obstructed, that the melted matter was forced to take a new course, and, running in a south-east direction, it discharged itself into the bed of the river Hverfisfliot, where a scene of destruction scarcely inferior to the former was occasioned. These Icelandic lavas, like the ancient streams which are met with in Auvergne, and other provinces of Central France, are stated by Stephensen to have accumulated to a prodigious depth in narrow rocky gorges, but when they came to wide alluvial plains, they spread themselves out into broad lakes of fire sometimes from twelve to fifteen miles wide, and one hundred feet deep. When the 'fiery lake' which filled up the lower portion of the valley of the Skaptâ had been augmented by new supplies, the lava flowed up the course of the river to the foot of the hills from whence the Skaptâ takes its rise. This affords a parallel case to one which can be shewn to have happened at a remote era in the volcanic region of the Vivarais in France, when lava issued from the cone of Thueyts, and while one branch ran down, another more powerful stream flowed up the river Ardêche.

The sides of the valley of the Skaptâ present superb ranges of basaltic columns of older lavas, resembling those which are laid open in the valleys descending from Mont Dor in Auvergne, where more modern lava-currents, on a scale very inferior in magnitude to those of Iceland, have also usurped the beds of the existing rivers. The eruption of Skaptár Jokul did not entirely cease till the end of two years; and when Mr. Paulson visited the tract eleven years afterwards, in 1794, he found

columns of smoke still rising from parts of the lava, and several rents filled with hot water *.

Although the population of Iceland did not exceed fifty thousand, no less than twenty villages were destroyed, besides those inundated by water, and an immense number of cattle, and more than nine thousand human beings perished, partly by the depredations of the lava, partly by the noxious vapours which impregnated the air, and, in part, by the famine caused by showers of ashes throughout the island, and the desertion of the coasts by the fish.

Immense volume of the lava.—We must now call the reader's particular attention to the extraordinary volume of melted matter produced in this eruption. Of the two branches, which flowed in nearly opposite directions, the greatest was fifty, and the lesser forty miles in length. The extreme breadth which the Skaptâ branch attained in the low countries was from twelve to fifteen miles, that of the other about seven. The ordinary height of both currents was one hundred feet, but in narrow defiles it sometimes amounted to six hundred. A more correct idea will be formed of the dimensions of the two streams, if we consider how striking a feature they would now form in the geology of England, had they been poured out on the bottom of the sea after the deposition, and before the elevation of our secondary and tertiary rocks. The same causes which have excavated valleys through parts of our marine strata, once continuous, might have acted with equal force on the igneous rocks, leaving, at the same time, a sufficient portion undestroyed, to enable us to discover their former extent. Let us, then, imagine the termination of the Skaptâ branch of lava to rest on the escarpment of the inferior and middle oolite, where it commands the vale of Gloucester. The great plateau might be one hundred feet thick, and from ten to fifteen miles broad, exceeding any which can be found in Central France. We may also suppose great tabular masses to occur at intervals, capping the summit of the Cotswold Hills between Gloucester

* Henderson's Journal, &c., p. 228.

and Oxford, by Northleach, Burford, and other towns. The wide valley of the Oxford clay would then occasion an interruption for many miles; but the same rocks might recur on the summit of Cumnor and Shotover Hills, and all the other oolitic eminences of that district. On the chalk of Berkshire, extensive plateaus, six or seven miles wide, would again be formed; and, lastly, crowning the highest sands of Highgate and Hampstead, we might behold some remnants of the deepest parts of the current five or six hundred feet in thickness, causing those hills to rival, or even to surpass, in height Salisbury Craigs and Arthur's Seat.

Volume of ancient and modern flows of lava compared.— The distance between the extreme points here indicated, would not exceed ninety miles in a direct line; and we might then add, at the distance of nearly two hundred miles from London, along the coast of Dorsetshire and Devonshire for example, a great mass of igneous rocks, to represent those of contemporary origin, which were produced beneath the level of the sea, where the island of Nyöe rose up. Yet, gigantic as must appear the scale of these modern volcanic operations, we must be content to regard them as perfectly insignificant in comparison to currents of the primeval ages, if we embrace the theoretical views of some geologists of great celebrity. We are informed by Professor Brongniart, in his last work, that 'aux époques géognostiques anciennes, tous les phénomènes géologiques se passoient dans des dimensions *centuples* de celles qu'ils présentent aujourd'hui *.' Had Skaptár Jokul therefore been a volcano of the olden time, it would doubtless have poured forth lavas at a single eruption, a hundred times more voluminous than those which were witnessed by the present generation in 1783. If we multiply the two currents before described, by a hundred, and first assume that their height and breadth remain the same, they would stretch out to the length of nine thousand miles, or about half as far again as from the pole to the equator. If, on the other hand, we suppose their length and breadth to

* Tableau des Terrains qui composent l'écorce du Globe, p. 52. Paris, 1829.

remain the same, and multiply their height in an equal proportion, the ordinary elevation of the volcanic mass becomes ten thousand feet, and its greatest more than double that of the Himalaya mountains. It will immediately be granted that, among the older formations, no igneous rock of such colossal magnitude has yet been met with, nay it would be most difficult to point out a mass of ancient date distinctly referrible to a single eruption, which should even rival in volume the matter poured out from Skaptár Jokul in 1783. These considerations, however, cannot present serious objections to geological theorists, for it is a received principle with them, that we ought always to assume the energies of natural forces to have been impaired and enfeebled, until the contrary can be shown; and as we have hitherto investigated but a small part of the globe, evidence may hereafter be brought to light of the superior violence of single volcanic eruptions in remote ages. If proofs be deficient, there is always a resource of which the geologist in Voltaire's tale knew how to avail himself, *Monsieur, on en découvrira* * !

Eruption of Jorullo in 1759.—As another example of the stupendous scale of modern volcanic eruptions, we may mention that of Jorullo in Mexico in 1759. We have already described the great region to which this mountain belongs. The plain of Malpais forms part of an elevated plateau, between two and three thousand feet above the level of the sea, and is bounded by hills composed of basalt, trachyte, and volcanic tuff, clearly indicating that the country had previously, though probably at a remote period, been the theatre of igneous action. From the era of the discovery of the New World to the middle of the last century, the district had remained undisturbed, and the space, now the site of the volcano, which is thirty-six leagues distant from the nearest sea, was occupied by fertile fields of sugar-cane and indigo, and watered by the two brooks Cuitimba and San Pedro. In the month of June, 1759, hollow sounds of an alarming nature were heard, and earthquakes suc-

* L'Homme aux quarante écus.

ceeded each other for two months, until, in September, flames issued from the ground, and fragments of burning rocks were thrown to prodigious heights. Six volcanic cones, composed of scoriæ and fragmentary lava, were formed on the line of a chasm which ran in the direction from N.N.E. to S.S.W. The least of these cones was three hundred feet in height and Jorullo, the central volcano, was elevated one thousand six hundred feet above the level of the plain. It sent forth great streams of basaltic lava, containing included fragments of primary rocks, and its ejections did not cease till the month of February, 1760.

Humboldt visited the country twenty years after the occurrence, and was informed by the Indians, that when they returned long after the catastrophe to the plain, they found the ground uninhabitable from the excessive heat. When the Prussian traveller himself visited the locality, there appeared, round the base of the cones, and spreading from them as from a centre over an extent of four square miles, a mass of matter five hundred and fifty feet in height in a convex form, gradually sloping in all directions towards the plain. This mass was still in a heated state, the temperature in the fissures being sufficient to light a cigar at the depth of a few inches. On this convex protuberance were thousands of flattish conical mounds, from six to nine feet high, which, as well as large fissures traversing the plain, acted as fumeroles, giving out clouds of sulphuric acid and hot aqueous vapour. The two small rivers before mentioned disappeared during the eruption, losing themselves below the eastern extremity of the plain, and reappearing as hot springs at its western limit.

Cause of the convexity of the Plain of Malpais.—Humboldt attributed the convexity of the plain to inflation from below, supposing the ground, for four square miles in extent, to have risen up in the shape of a bladder, to the elevation of five hundred and fifty feet above the plain in the highest part. But this theory, which is entirely unsupported by analogy, is by no means borne out by the facts described; and it is the more

necessary to scrutinize closely the proofs relied on, because the opinion of Humboldt appears to have been received as if founded on direct observation, and has been made the groundwork of other bold and extraordinary theories. Mr. Scrope has suggested that the phenomena may be accounted for far more naturally, by supposing that lava flowing simultaneously from the different orifices, and principally from Jorullo, united into a sort of pool or lake. As they were poured forth on a surface previously flat, they would, if their liquidity was not very great, remain thickest and deepest near their source, and diminish in bulk from thence towards the limits of the space which they covered. Fresh supplies were probably emitted successively during the course of an eruption which lasted a year, and some of these resting on those first emitted, might only spread to a small distance from the foot of the cone, where they would necessarily accumulate to a great height.

The showers, also, of loose and pulverulent matter from the six craters, and principally from Jorullo, would be composed of heavier and more bulky particles near the cones, and would raise the ground at their base, where, mixing with rain, they might have given rise to the stratum of black clay which is described as covering the lava. The small conical mounds (called 'hornitos' or ovens) may resemble those five or six small hillocks which existed in 1823 on the Vesuvian lava, and sent forth columns of vapour, having been produced by the disengagement of elastic fluids heaving up small dome-shaped masses of lava. The fissures mentioned by Humboldt as of frequent occurrence are such as might naturally accompany the consolidation of a thick bed of lava, contracting as it congeals; and the disappearance of rivers is the usual result of the occupation of the lower part of a valley or plain by lava, of which there are many beautiful examples in the old lava-currents of Auvergne. The heat of the 'hornitos' is stated to have diminished from the first, and Mr. Bullock, who visited the spot many years after Humboldt, found the temperature of the hot spring very low, a fact which seems clearly to indicate the

gradual congelation of a subjacent bed of lava, which from its immense thickness may have been enabled to retain its heat for half a century. We may remind the reader that, when we thus suppose the lava near the volcano to have been, together with the ejected ashes, more than five hundred feet in depth, we merely assign a thickness which the current of Skaptár Jokul attained in some places in 1783.

Hollow sound of the plain when struck.—Another argument adduced in support of the theory of inflation from below was the hollow sound made by the steps of a horse upon the plain, which however proves nothing more than that the materials of which the convex mass is composed are light and porous. The sound called 'rimbombo' by the Italians is very commonly returned by *made ground* when struck sharply, and has been observed not only on the sides of Vesuvius and other volcanic cones where there is a cavity below, but in plains such as the Campagna di Roma, composed in great measure of tuff and porous volcanic rocks. The reverberation, however, may perhaps be assisted by grottos and caverns, for these may be as numerous in the lavas of Jorullo as in many of those of Etna; but their existence would lend no countenance to the hypothesis of a great arched cavity, or bubble, four square miles in extent, and in the centre five hundred and fifty feet high *.

Recent eruption of Jorullo.—A subsequent eruption of Jorullo happened in 1819, accompanied by an earthquake; but unfortunately no European travellers have since visited the spot, and the only facts hitherto known are that ashes fell at the city of Guanaxuato, which is distant about one hundred and forty English miles from Jorullo, in such quantities as to lie six inches deep in the streets, and the tower of the cathedral of Guadalaxara was thrown down †.

* See Scrope on Volcanos, p. 267.

† For this information I am indebted to Captain Vetch, F.R.S.

CHAPTER XXII.

Volcanic archipelagos—The Canaries—Eruptions of the Peak of Teneriffe—Cones thrown up in Lancerote in 1730-36—Pretended distinction between ancient and modern lavas—Recent formation of oolitic travertin in Lancerote—Grecian Archipelago—Santorin and its contiguous isles—New islands thrown up in the Gulf of Santorin—Von Buch's Theory of 'Elevation Craters' consi-sidered—Supposed 'Crater of Elevation' in the Isle of Palma—Description of the Caldera of Palma—Barren island in the Bay of Bengal—Origin of the deep gorge on the side of 'Elevation Craters'—Stratification of submarine volcanic products—Causes of the great size of the craters of submarine volcanos—Cone of Somma formed in the same manner as that of Vesuvius—Mineral composition of volcanic products—Speculations respecting the nature of igneous rocks produced at great depths by modern volcanic eruptions.

Volcanic archipelagos.—In our chronological sketch of the changes which have happened within the traditionary and historical period in the volcanic district round Naples, we described the renewal of the fires of a central and habitual crater, and the almost entire cessation of a series of irregular eruptions from minor and independent vents. Some volcanic archipelagos offer interesting examples of the converse of this phenomenon, the great habitual vent having become almost sealed up, and eruptions of great violence now proceeding, either from different points in the bed of the ocean, or from adjoining islands, where, as formerly in Ischia, new cones and craters are formed from time to time. Of this state of things the Canary Islands now afford an example.

Peak of Teneriffe.—The highest crater of the Peak of Teneriffe has been in the state of a solfatara ever since it has been known to Europeans; but several eruptions have taken place from the sides of the mountain, one in the year 1430, which formed a small hill, and another in 1704 and the two following years, accompanied with great earthquakes, when the lava overflowed a town and harbour. Another eruption happened in June, 1798, not far from the summit of the peak. But

these lateral emissions of lava, at distant intervals, may be considered as of a subordinate kind, and subsidiary to the great discharge which has taken place in the contiguous isles of Palma and Lancerote; and the occasional activity of the peak may be compared to the irregular eruptions before mentioned, of the Solfatara, of Arso in Ischia, and of Monte Nuovo, which have broken out since the renewal of the Vesuvian fires in 79.

Eruption in Lancerote, 1730 *to* 1736.—We shall describe one of these insular eruptions in the Canaries, which happened in Lancerote, between the years 1730 and 1736, as the effects were remarkable; and Von Buch had an opportunity, when he visited that island in 1815, of comparing the accounts transmitted to us of the event with the present state and geological appearances of the country *. On the 1st of September, 1730, the earth split open on a sudden two leagues from Yaira. In one night a considerable hill of ejected matter was thrown up, and a few days later, another vent opened, and gave out a lava-stream, which overran Chinanfaya and other villages. It flowed first rapidly, like water, but became afterwards heavy and slow, like honey. On the 7th of September an immense rock was protruded from the bottom of the lava, with a noise like thunder, and the stream was forced to change its course from N. to N. W., so that St. Catalina and other villages were overflowed. Whether this mass was protruded by an earthquake, or was a mass of ancient lava, blown up like that before mentioned in 1783 in Iceland, is not explained. On the 11th of September more lava flowed out, and covered the village of Maso entirely, and, for the space of eight days, precipitated itself with a horrible roar into the sea. Dead fish floated on the waters in indescribable multitudes, or were thrown dying on the shore. After a brief interval of repose, three new openings broke forth immediately from the site of the consumed

* This account was principally derived by Von Buch from the MS. of Don Andrea Lorenzo Curbeto, Curate of Yaira, the point where the eruption began.—Uber einen vulcanisch. Ausbruch auf der Insel Lanzerote.

St. Catalina, and sent out an enormous quantity of lapilli, sand, and ashes. On the 28th of October, the cattle throughout the whole country dropped lifeless to the ground, suffocated by putrid vapours, which condensed and fell down in drops. On the 1st of December a lava-stream reached the sea, and formed an island round which dead fish were strewed.

Number of cones thrown up.—It is unnecessary here to give the details of the overwhelming of other places by fiery torrents, or of a storm which was equally new and terrifying to the inhabitants, as they had never known one in their country before. On the 10th of January, 1731, a high hill was thrown up, which, on the same day, precipitated itself back again into its own crater: fiery brooks of lava flowed from it to the sea. On the 3rd of February a new cone arose. Others were thrown up in March, and poured forth lava-streams. Numerous other volcanic cones were subsequently formed in succession, till at last their number amounted to about thirty. In June, 1731, during a renewal of the eruptions, all the banks and shores in the western part of the island were covered with dying fish, of different species, some of which had never before been seen. Smoke and flame arose from the sea, with loud detonations. These dreadful commotions lasted without interruption for *five successive years*, and a great emigration of the inhabitants became necessary.

Their linear direction.—As to the height of the new cones, Von Buch was assured that the formerly great and flourishing St. Catalina lay buried under hills 400 feet in height; and he observes that the most elevated cone of the series rose 600 feet above its base, and 1378 feet above the sea, and that several others were nearly as high. The new vents were all arranged *in one line*, about two geographical miles long, and in a direction nearly east and west. If we admit the probability of Von Buch's conjecture, that these vents opened along the line of an open cleft, it seems necessary to suppose that this subterranean fissure was only prolonged upwards to the surface by degrees, or that the rent was narrow at first, as is usually the case with

fissures caused by earthquakes. Lava and elastic fluids might escape from some point on the rent where there was least resistance, till the first aperture becoming obstructed by ejections and the consolidation of lava, other orifices burst open in succession, along the line of the original fissure. Von Buch found that each crater was lowest on that side on which lava had issued; but some craters were not breached, and were without any lava-streams. In one of these were open fissures, out of which hot vapours rose, which in 1815 raised the thermometer to 145° Fahrenheit, and was probably at the boiling point lower down. The exhalations seemed to consist of aqueous vapour, yet they could not be pure steam, for the crevices were encrusted on either side by siliceous sinter (an opal-like hydrate of silica, of a white colour), which extended almost to the middle. This important fact attests the length of time during which chemical processes continue after eruptions, and how open fissures may be filled up laterally by mineral matter, sublimed from volcanic exhalations. The lavas of this eruption covered nearly a third of the whole island, often forming on slightly-inclined planes great horizontal sheets several square leagues in area, resembling very much the basaltic plateaus of Auvergne.

Pretended distinction between ancient and modern lavas.— One of the new lavas was observed to contain masses of olivine of an olive-green colour, resembling those which occur in one of the lavas of the Vivarais. Von Buch supposes the great crystals of olivine to have been derived from a previously existing basalt, melted up by the new volcanos, but sufficient data are not furnished for warranting such a conjecture. The older rocks of the island consist, in a great measure, of that kind of basaltic lava called dolerite, sometimes columnar, and of common basalt and amygdaloid. Some recent lavas assumed, on entering the sea, a prismatic form, and so much resembled the older lavas of the Canaries, that the only geological distinction which Von Buch appears to have been able to draw between them was, that they did not alternate

with conglomerates, like the ancient basalts. Some modern writers have endeavoured to discover, in the abundance of these conglomerates, a proof of the dissimilarity of the volcanic action in ancient and modern times; but this character is more probably attributable to the difference between submarine operations and those on the land. All the blocks and imperfectly rounded fragments of lava, transported, during the intervals of eruption by rivers and torrents, into the adjoining sea, or torn by the continued action of the waves from cliffs which are undermined, must accumulate in stratified breccias and conglomerates, and be covered again and again by other lavas. This is now taking place on the shores of Sicily, between Catania and Trezza, where the sea breaks down and covers the shore with blocks and pebbles of the modern lavas of Etna; and on parts of the coast of Ischia, where numerous currents of trachyte are in like manner undermined in lofty precipices. So often then as an island is raised in a volcanic archipelago by earthquakes from the deep, the fundamental and (relatively to all above) the oldest lavas will often be distinguishable from those formed by subsequent eruptions on dry land, by their alternation with beds of sandstone and fragmentary rocks.

The supposed want of identity then between the volcanic phenomena of different epochs resolves itself into the marked difference between the operations simultaneously in progress, above and below the water. Such, indeed, is the source, as we stated in our fifth chapter, of many of our strongest theoretical prejudices in geology. No sooner do we study and endeavour to explain submarine appearances, than we feel, to use a common expression, *out of our element;* and, unwilling to concede that our extreme ignorance of processes now continually going on can be the cause of our perplexity, we take refuge in a 'pre-existent order of nature.'

Recent formation of oolitic travertin in Lancerote.—Throughout a considerable part of Lancerote, the old lavas are covered by a thin stratum of limestone, from an inch to two feet in

thickness. It is of a hard stalactitic nature, sometimes oolitic, like the Jura limestone, and contains fragments of lava and terrestrial shells, chiefly helices and spiral bulimi. Von Buch imagines, that this remarkable superstratum has been produced by the furious north-west storms, which in winter drive the spray of the sea in clouds over the whole island; from whence calcareous particles may be deposited stalactitically. If this explanation be correct, and it seems highly probable, the fact is interesting, as attesting the quantity of matter held in solution by the sea-water, and ready to precipitate itself in the form of solid rock. At the bottom of such a sea, impregnated, as in the neighbourhood of all active volcanos, with mineral matter in solution, lavas must be converted into calcareous amygdaloids, a form in which the igneous rocks so frequently appear in the older European formations. We may mention that recent crevices in the rocks of Trezza, one of the Cyclopian isles at the foot of Etna, are filled with a kind of travertin, as high as the spray of the sea reaches; and in this hard veinstone, fragments, and even entire specimens of recent shells thrown up by the waves, are sometimes included.

Recent eruption in Lancerote.—From the year 1736 to 1815, when Von Buch visited Lancerote, there had been no eruption; but, in August, 1824, a crater opened near the port of Rescif, and formed, by its ejections, in the space of twenty-four hours, a considerable hill. Violent earthquakes preceded and accompanied this eruption*.

Grecian Archipelago.—We shall next direct our inquiry to the island of Santorin, as it will afford us an opportunity of discussing the merits of a singular theory, which has obtained no small degree of popularity in modern times, respecting 'craters of elevation,' (Erhebungs Cratere, Cratères de soulèvement,) as they have been termed. The three islands of Santorin, Therasia, and Aspronisi surround a gulf almost circular, and above six miles in diameter. They

* Férussac, Bulletin des Sci. Nat., tome v. p. 45.—1825. The volcano was still burning when the account here cited was written.

are chiefly composed of trachytic conglomerates and tuffs, covered with pumice; but in one part of Santorin clay-slate is seen to be the fundamental rock. The beds in all these isles

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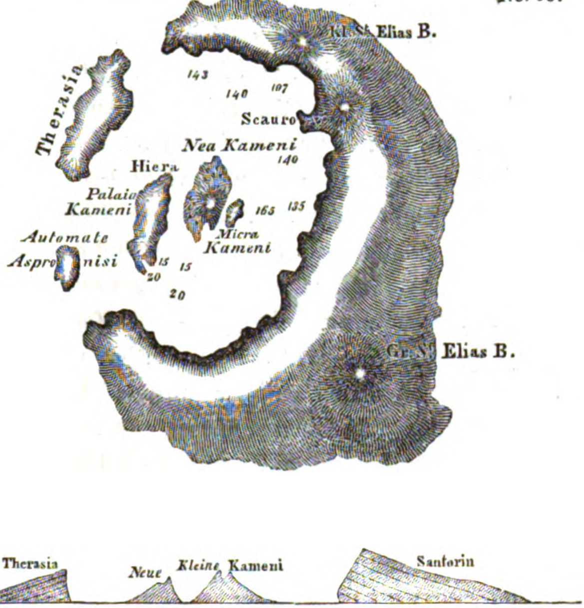


Chart and Section of Santorin and the contiguous islands in the Grecian Archipelago.

dip at a slight angle towards the exterior of the group, and lose themselves in the surrounding sea; whereas, on the contrary, they present a high and steep escarpment towards the centre of the inclosed space. The gulf, therefore, is nearly on all sides environed by precipices; those of Santorin, which form two-thirds of the circumference, being two leagues in extent, and in some parts three hundred feet high. These rocky cliffs plunge at once into the sea, so that close to the shore soundings are only reached at a depth of eight hundred feet, and at a little distance farther at a depth of one thousand feet.

New islands in the gulf of Santorin.—In the middle of this gulf, the small isle of Hiera, now called Palaia Kameni, rose up, 144 years before the Christian era. In 1427 this isle received new accessions. In 1573 the Little Kameni was raised

in the middle of the basin, its elevation being accompanied by the discharge of large quantities of pumice and a great disengagement of vapour. Lastly, in 1707 and 1709 the New Kameni was formed, which still exhales sulphureous vapours. These isles are formed of rocks of brown trachyte, which has a resinous lustre, and is full of crystals of glassy felspar. Although the birth of New Kameni was attended by an eruption, it is certain that it was upraised from a great depth by earthquakes, and was not a heap of volcanic ejections, nor of lava poured out on the spot. There were shells upon it when it first appeared; and beds of limestone and marine shells are described by several authors as entering, together with igneous rocks, into the structure of other parts of this group.

Theory of 'elevation craters.'—In order, therefore, to explain the formation of such circular gulfs, which are common in other archipelagos, Von Buch supposes, and Humboldt adopts the same opinion, that the different beds of lava, pumice, and whatever else may be interstratified, were first horizontally disposed along the floor of the ocean. An expansive force from below then burst an opening through them, and, acting towards a central point, raised symmetrically on every side all which resisted its action; so that the uplifted strata were made to dip away on all sides from the centre outwards, as is usual in volcanic cones, while a deep hollow was left in the middle, resembling in all essential particulars an ordinary volcanic crater.

In the first instance we should inform the reader, that this theory is not founded on actual observations of analogous effects produced by the elevating forces of earthquakes, or the escape of elastic fluids in any part of the globe; for the inflation from below of the rocks in the plain of Malpais, during the eruption of Jorullo, was, as before stated, an hypothesis proposed, long after that eruption, to account for appearances which admit of a very different explanation. Besides, in the case of Jorullo, there was no great 'crater of elevation' formed in the centre. All our modern analogies, therefore, being in favour of the origin of cones and craters exclusively by *erup-*

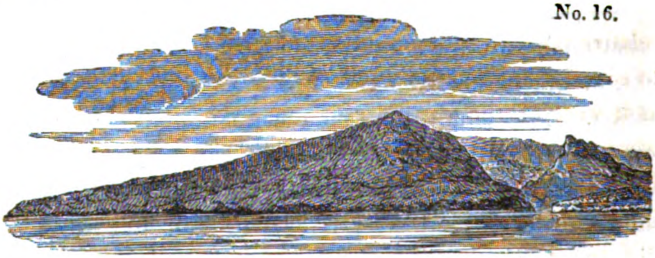
tions, we are entitled to scrutinize with no small severity the new hypothesis; and we have a right to demand demonstrative evidence, that known and ordinary causes are perfectly insufficient to produce the observed phenomena. Had Von Buch and Humboldt, for instance, in the course of those extensive travels which deservedly render their opinions, in regard to all volcanic operations, of high authority, discovered a single cone composed exclusively of marine or lacustrine strata, without a fragment of any igneous rock intermixed,—and in the centre a great cavity, encircled by a precipitous escarpment,—then we should have been compelled at once to concede, that the cone and crater-like configuration, whatever be its mode of formation, may sometimes have no reference whatever to ordinary volcanic eruptions.

But it is not pretended that, on the whole face of the globe, a single example of this kind can be pointed out. In Europe and North America thousands of square leagues of territory have been examined, composed of marine strata, which have been elevated to various heights, sometimes to more than ten thousand feet above the level of the sea, sometimes in horizontal tabular masses; in other cases with every degree of inclination, from the horizontal to the vertical. Some have been moved without great derangement, others have been rent, contorted, or shattered with the utmost violence. Sometimes large districts, at others small spaces, appear to have changed their position. Yet, amidst the innumerable accidents to which these rocks have been subject, never have they assumed that form, exactly representing a large truncated volcanic cone, with a great cavity in the centre. Are we then called upon to believe that whenever elastic fluids generated in the subterranean regions burst through horizontal strata, so as to upheave them in the peculiar manner before adverted to, they always select, as if from choice, those spots of comparatively insignificant area, where a certain quantity of volcanic matter happens to lie, while they carefully avoid purely lacustrine and marine strata, although they often lie immediately contiguous? Why

on the southern borders of the Limagne d'Auvergne, where several eruptions burst through, and elevated the horizontal marls and limestones, did these fresh-water beds never acquire in any instance a conical and crateriform disposition?

Supposed 'Crater of Elevation' in the Isle of Palma.—But let us proceed to examine some of the most celebrated examples adduced of craters of elevation. The most perfect type of this peculiar configuration is said to be afforded by the Isle of Palma; and while we controvert Von Buch's theoretical opinions, we ought not to forget how much geology is indebted to his talents and zeal, and amongst other works for his clear and accurate description of this isle*. In the middle of Palma rises a mountain to the height of four thousand feet, presenting the general form of a great cone, the upper part of which had been truncated and replaced by an enormous funnel-shaped cavity, about four thousand feet deep; and the surrounding borders of which attain, at their highest point, an elevation of seven thousand feet above the sea. The external flanks of this cone are gently inclined, and, in part, cultivated; but the bottom and the walls of the central cavity, called by the inhabitants the Caldera, present on all sides rugged and uncultivated rocks, almost completely devoid of vegetation.

No. 16.



View of the Isle of Palma, and of the Caldera in its centre.

So steep are the sides of the Caldera, that there is no path by which they can be descended; and the only entrance is by a great ravine, which cutting through the rocks environing the circus, runs down to the sea. The sides of this gorge are

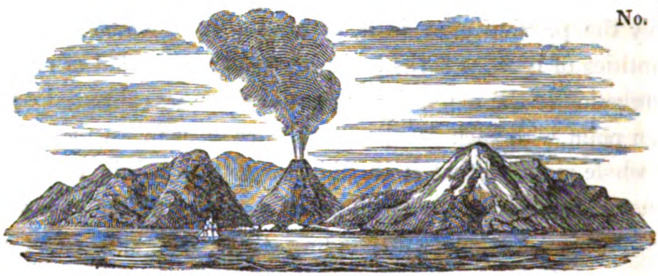
* Physical. Besch. der Canarischen Inseln. Berlin, 1825.

jagged, broken, and precipitous. In the mural escarpments surrounding the Caldera are seen nothing but beds of basalt, and conglomerates composed of broken fragments of basalt, which dip away with the greatest regularity, from the centre to the circumference of the cone. Now, according to the theory of 'elevation craters,' we are called upon to suppose that, in the first place, a series of horizontal beds of volcanic matter accumulated over each other, to the enormous depth of more than four thousand feet—a circumstance which alone would imply the proximity, at least, of a vent from which immense quantities of igneous rocks had proceeded: next that after the aggregation of the mass, the expansive force was directed on a given point with such extraordinary energy, as to lift up bodily the whole mass, so that it should rise to the height of seven thousand feet above the sea, leaving a great gulf or cavity in the middle. Yet, notwithstanding this prodigious effort of gaseous explosions, concentrated on so small a point, the beds, instead of being shattered, contorted, and thrown into the utmost disorder, have acquired that gentle inclination, and that regular and symmetrical arrangement, which characterize the flanks of a large cone of eruption, like Etna! We admit that earthquakes, when they act on extensive tracts of country, may elevate and depress them without deranging, considerably, the relative position of hills, valleys, and ravines. But is it possible to conceive that elastic fluids could break through a mere point as it were of the earth's crust, and that too where the beds were not composed of soft, yielding clay, or incoherent sand, but of solid basalt, thousands of feet thick, and that they could inflate them, as it were, in the manner of a bladder? Would not the rocks, on the contrary, be fractured, fissured, thrown into a vertical, and often into a reversed position; and, ere they attained the height of seven thousand feet, would they not be reduced to a mere confused and chaotic heap?

Barren Island not a crater of elevation.—The Great Canary is an island of a circular form, analogous to that of Palma. Barren Island, also, in the Bay of Bengal, is proposed as a

striking illustration of the same phenomenon; and here it is said we have the advantage of being able to contrast the ancient crater of elevation with a cone and crater of eruption in its centre. When seen from the ocean, this island presents, on almost all sides, a surface of bare rocks, which rise up with a moderate declivity towards the interior; but at one point there is a narrow cleft, by which we can penetrate into the centre, and there discover that it is occupied by a great cir-

No. 17.



Cone and Crater of Barren Island, in the Bay of Bengal.

cular basin filled by the waters of the sea, bordered all around by steep rocks, in the midst of which rises a volcanic cone, very frequently in eruption. The summit of this cone is 1690 French feet in height, corresponding to that of the circular border which incloses the basin; so that it can only be seen from the sea through the ravine, which precisely resembles the deep gorge by which we penetrate into the Caldera of the Isle of Palma, and of which an equivalent, more or less decided in its characters, is said to occur in all elevated craters.

Peak of Teyda—Teneriffe.—The cone of the high peak of Teyda, in Teneriffe, is also represented as rising out of the middle of a crater of elevation, standing like a tower surrounded by its foss and bastion; the foss being the remains of the ancient gulf, and the bastion the escarpment of the circular inclosure. So that Teneriffe is an exact counterpart of Barren Island, except that one is raised to an immense height, while the other is still on a level with the sea, and in part concealed beneath its waters.

Now, without enumerating more examples, let us consider what form the products of submarine volcanos may naturally be expected to assume. There is every reason to conclude, from the few accounts which we possess of eruptions at the bottom of the sea, that they take place in the same manner there as on the open surface of a continent *. That the volcanic phenomena, if they are ever developed at unfathomable depths, may be extremely different, is very possible; but when they have been witnessed by the crews of vessels casually passing, the explosions of aëriform fluids beneath the waters have closely resembled those of volcanos on the land. Rocky fragments, ignited scoriæ and comminuted ashes, are thrown up, and in several cases conical islands have been formed, which afterwards disappeared; as when, in 1691 and 1720, small isles were thrown up off St. Michael in the Azores, or as Sabrina rose in 1811 near the same spot, and, in 1783, Nyöe, off the coast of Iceland, and in July 1831, the new isle of Sciacca in Sicily. Where the cones have disappeared, they probably consisted of loose matters, easily reduced by the waves and currents to a submarine shoal. When islands have remained firm, as in the case of Hiera, and the New and Little Kameni in the Gulf of Santorin (see wood-cut No. 15), they have consisted in part of solid lava.

Whatever doubts might have been entertained as to the action of volcanos entirely submarine, yet it must always have been clear, that in those numerous cases where they just raise their peaks above the waves, the ejected sand, scoriæ, and fragments of rock must accumulate round the vent into a cone with a central crater, while the lighter will be borne to a distance by tides and currents, as by winds during eruptions in open air. The lava which issues from the crater spreads over the subaqueous bottom, seeking the lowest levels, or accumulating upon itself, according to its liquidity, volume, and rapidity of congelation; following, in short, the same laws as when flowing in the atmosphere †.

* Scrope on Volcanos, p. 171. † Ib. 173.

Stratification of submarine volcanic products.—But we may next inquire, what characters may enable a geologist to distinguish between cones formed entirely, or in great part beneath the waters of the sea, and those formed on land. In the first place, large beds of shells and corals often grow on the sloping sides of submarine cones, particularly in the Pacific, and these often become interstratified with lavas. Instead of alluvions containing land-shells, like some of those which cover Herculaneum, great beds of tufaceous sand and conglomerate, mixed with marine remains, might be expected on such parts of the flanks of a volcano like Stromboli as are submerged beneath the waters. The pressure of a column of water, exceeding many times that of the atmosphere, must impede the escape of the elastic fluids and of lava, until the resistance is augmented in the same proportion; hence the explosions will be more violent, and when a cone is formed it will be liable to be blown up and truncated at a lower level than in shallower water or in the open air. Add to this, that when a submarine volcano has repaired its cone, it is liable to be destroyed again by the waves, as in several cases before adverted to. The vent will then become choked up with strata of sand and fragments of rock, swept in by the tides and currents. These materials are far more readily consolidated under water than in the air, especially as mineral matter is so copiously introduced by the springs which issue from the ground in all volcanic regions hitherto carefully investigated. Beds of solid travertin, also, and in hot countries coral reefs, must often, during long intervals of quiescence, obstruct the vent, and thus increase the repressive force and augment the violence of the eruptions.

Dimensions of 'craters of elevation.'—The probabilities, therefore, in a submarine volcano, of the destruction of a larger part of the cone, and the formation of a more extensive crater, are obvious; nor can the dimensions of 'craters of elevation,' if referred to such operations, surprise us. During an eruption in 1444, accompanied by a tremendous earthquake, the summit of Etna was destroyed, and an enormous crater was left, from

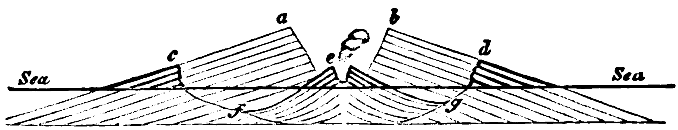
which lava flowed. The segment of that crater may still be seen near the Casa Inglese, and, when complete, it must have measured several miles in diameter. The cone was afterwards repaired but this would not have happened so easily had Etna been placed like Stromboli in a deep sea, with its peak exposed to the fury of the waves. Let us suppose the Etnean crater of 1444 to have been filled up with beds of coral and conglomerate, and that during succeeding eruptions these were thrown out by violent explosions, so that the cone became truncated down to the upper margin of the woody region, a circular basin would then be formed thirty Italian miles in circumference, exceeding by five or six miles the circuit of the Gulf of Santorin. Yet we know by numerous sections that the strata of trachyte, basalt, and trachytic breccia, would, in that part of the great cone of Etna, dip on all sides off from the centre at a gentle angle to every point of the compass, except where irregularities were occasioned, at points where the small buried cones before mentioned occurred. If this gulf were then again choked up, and the vent obstructed, so that new explosions of great violence should truncate the cone once more down to the inferior border of the forest zone of Etna, the circumference of the gulf would then be fifty Italian miles *. Yet even then the ruins of the cone of Etna might form a circular island entirely composed of volcanic rocks, sloping gently outwards on all sides at a very slight angle; and this island might be between seventy and eighty English miles in its exterior circuit, while the circular bay within might be between forty and fifty miles round. In fertility it would rival the Island of Palma; and the deep gorge which leads down from the Valley of Calanna to Zafarana, might well serve as an equivalent to the grand defile which leads into the Caldera.

Restoration of Barren Island.—It is most probable, then, that the exterior inclosure of Barren Island, *c*, *d*, (diagram 18,) is nothing more than the remains of the truncated cone, *c*, *a*, *b*, *d*,

* For the measurements of different parts of the cone of Etna, see Trattato dei boschi dell' Etna, Scuderi, Acti. dell' Acad. Gion. de Catan., vol. i.

a great portion of which has been carried away, partly by the action of the waves, and partly by explosions which preceded the formation of the new interior cone, *f, e, g*. Whether the

No. 18.



Supposed Section of Barren Island, in the Bay of Bengal.

outer and larger cone has, in this particular case, together with the bottom of the ocean on which it rests, been upheaved, or whether it originally projected in great part like Stromboli above the level of the sea, may, probably, be determined by geological investigations; for, in the former case, some beds replete with marine remains may be interstratified with volcanic ejections.

Some of the accounts transmitted to us by eye-witnesses, of the gradual manner in which New Kameni first rose covered with living shells in the Gulf of Santorin, appear, certainly, to establish the possibility of the elevation of small masses from a depth of several hundred feet during an eruption, and during the emission of lava. But the protrusion of isolated masses, under such circumstances, affords no analogy to the supposed action of the expansive force in the formation of craters of elevation. It is hardly necessary, after the observations now made, to refer the reader again to our section of Somma and Vesuvius, and to say that we ascribed the formation of the ancient and the modern cone to operations precisely analogous.

M. Necker * long ago pointed out the correspondence of their structure, and explained most distinctly the origin of the form of Somma; and his views were afterwards confirmed by Mr. Scrope. But, notwithstanding the juxtaposition of the entire and the ruined cone, the identity of the slope and quâ-quâ-versal dip of the beds, the similarity of their mineral com-

* Mémoire sur le Mont Somma, Mém. de la Soc. de Phys. et d'Hist. Nat. de Genève, tom. ii. part i. p. 155.

position, and the intersection of both cones by porphyritic dikes, the defenders of the 'elevation' theory have declared that the lavas and breccias of Somma were once horizontal, and were afterwards raised into a conical mass, while they admit that those in Vesuvius have always been as highly inclined as they are now.

In controverting Von Buch's theory, we might have adduced, as the most conclusive argument against it, that it would lead its advocates, if consistent with themselves, to the extravagant conclusion, that the two cones of Vesuvius had derived their form from very distinct causes. But as these geologists are not afraid to follow their system into all its consequences, and have even appealed to Somma as confirmatory of their views, it would be vain to hope, by pointing out the closest analogies between the effects of ordinary volcanic action and 'craters of elevation,' to induce them to abandon their hypothesis.

Older part of Etna not a 'Crater of Elevation.'—The marine shelly strata, interstratified with basalt, through which the great cone of Etna rises, are also said to have constituted an ancient crater of elevation; but when we allude more particularly to the geology of Sicily, it will appear that the strata in question do not dip so as to countenance in the least degree such an hypothesis. The nearest approach, perhaps, to the production of a conical mass by elevation from below, is in the Cantal in Central France. The volcanic eruptions which produced, at some remote period, the volcanic mountain called the Plomb du Cantal, broke up through fresh-water strata, which must have been deposited originally in an horizontal position, on rocks of granitic schist. During the gradual formation of the great cone, beds of lava and tuff, thousands of feet in thickness, were thrown out from one or more central vents, so as to cover great part of the lacustrine strata, and these at the same time were traversed by dikes, and in parts lifted up together with the subjacent granitic rocks; so that if the igneous products could now be removed, and the marls, limestones, and fundamental schists, supported at their present elevation, they

would form a kind of dome-shaped protuberance. But the outline of this shattered mass would be very unlike that of a regular cone, and the dip of the beds would be often horizontal, as near Aurillac, often vertical, often reversed, nor would there be in the centre any great cavity or crater of elevation *. On the other hand, the *volcanic* beds of the Plomb du Cantal are arranged in a conical form, like those of Etna, not by elevation from below, but because they flowed down during successive eruptions *from above.*

Origin of the deep gorge in Elevation Craters.—In regard to the deep channel of communication which appears always to connect the central cavity of the so-called 'Elevation Craters' with the sea, it may be ascribed, we think, to the action of the tides, during the gradual and successive upheaving of a volcanic isle. But to this subject we shall more particularly advert when we inquire into the causes of the configuration of coral islands †.

Isle of Sciacca‡, July, 1831.—A new island began to rise in the Mediterranean, on the 17th of July, 1831, on a spot thirty miles south-west of the town of Sciacca, in Sicily, and thirty-three miles north-east of the island of Pantellaria §. Captain W. H. Smyth had ascertained during his survey, a few years before, that there was a depth of one hundred fathoms on this precise spot. It is not known when the submarine eruption began, but shocks of an earthquake were felt in a ship on the spot about a month before the island rose, and the captain of a Sicilian vessel had found the sea, at the distance of eight miles from the site of the volcano, covered with dead and half-killed fish. On the 12th of July floating cinders were observed in such quantity on the coast near

* See a Memoir by Messrs. Murchison and Lyell, Sur les Dépôts Lacustres Tertiaires du Cantal, &c., Ann. des Sci. Nat., October, 1829.

† Vol. II. ch. xviii.

‡ I select this name out of six that have been proposed, as it serves to fix the nearest town in the memory.

§ Journ. of Roy. Geograph. Soc., 1830-31, with a figure.

Sciacca, at a distance of thirty-seven miles, that fishermen were obliged to part them with their oars, in order to give passage to their boats. They found at the same time newly killed fish on the surface of the water, which they sold in Sciacca *.

The island increased in size from the 16th of July to the 16th of August, at which time it was ascertained to be 3240 feet in its greatest circumference, its greatest height 107 feet, and the circumference of its crater about 780 feet. The mass consisted of brown sand and scoriæ, with some ejected fragments of lava, and a few pieces of limestone, but no lava flowed from the crater. During the winter of 1831, the whole isle was swept away by the waves, and a shoal is said to remain in its place.

As we know the sea to have been 600 feet deep in the spot a few years previously, this volcano was probably a cone of single eruption, like some of those of still greater height on the flanks of Etna, or that of Jorullo, in 1759, which attained an elevation of 1600 feet in about nine months.

Mineral Composition of Volcanic Products.—The mineral called felspar, forms in general more than half of the mass of modern lavas. When it is in great excess, lavas are called trachytic; when augite (or pyroxene) predominates, they are termed basaltic. But lavas of composition, precisely intermediate, occur, and from their colour have been called graystones. A great abundance of quartz characterizes the granitic and other ancient rocks, now generally considered by geologists as of igneous origin, whereas that mineral, which is nothing more than silex crystallized, is rare in recent lavas, although silex enters largely into their composition. Hornblende, which is so common in ancient rocks, is rare in modern lava, nor does it enter largely into rocks of any age in which augite abounds. Mica occurs plentifully in some recent trachytes, but is rarely present where augite is in excess. We must

* Hoffman, Proceedings of the Geol. Soc., No. xxiii. p. 339.

beware, however, not to refer too hastily to a difference of era, characters which may, in truth, belong to the different circumstances under which the products of fire originate.

Speculations respecting the nature of igneous rocks produced at great depths by modern volcanic eruptions.—When we speak of the igneous rocks of our own times, we mean that small portion which happens in violent eruptions to be forced up by elastic fluids to the surface of the earth. We merely allude to the sand, scoriæ, and lava, which cool in the open air; but we cannot obtain access to that which is congealed under the pressure of many hundred, or many thousand atmospheres. We may, indeed, see in the dikes of Vesuvius rocks consolidated from a liquid state, under a pressure of perhaps a thousand feet of lava, and the rock so formed is more crystalline and of greater specific gravity than ordinary lavas. But the column of melted matter raised above the level of the sea during an eruption of Vesuvius must be more than three thousand feet in height, and more than ten thousand feet in Etna; and we know not how many miles deep may be the ducts which communicate between the mountain and those subterranean lakes or seas of burning matter which supply for thousands of years, without being exhausted, the same volcanic vents. The continual escape of hot vapours from many craters during the interval between eruptions, and the chemical changes which are going on for ages in the fumeroles of volcanos, prove that the volcanic foci retain their intense heat constantly, nor can we suppose it to be otherwise; for as lava-currents of moderate thickness require many years to cool down in the open air, we must suppose the great reservoirs of melted matter at vast depths in the nether regions to preserve their high temperature and fluidity for thousands of years.

During the last century, about fifty eruptions are recorded of the five European volcanos, Vesuvius, Etna, Volcano, Santorin, and Iceland, but many beneath the sea in the Grecian Archipelago and near Iceland may doubtless have passed unnoticed. If some of them produced no lava, others on the contrary, like

that of Skaptár Jokul in 1783, poured out melted matter for five or six years consecutively, which cases, being reckoned as single eruptions, will compensate for those of inferior strength. Now, if we consider the active volcanos of Europe to constitute about a fortieth part of those already known on the globe, and calculate, that, one with another, they are about equal in activity to the burning mountains in other districts, we may then compute that there happen on the earth about two thousand eruptions in the course of a century, or about twenty every year.

However inconsiderable, therefore, may be the superficial rocks which the operations of fire produce on the surface, we must suppose the subterranean changes now constantly in progress to be on the grandest scale. The loftiest volcanic cones must be as insignificant, when contrasted to the products of fire in the nether regions, as are the deposits formed in shallow estuaries when compared to submarine formations accumulating in the abysses of the ocean. In regard to the characters of these volcanic rocks, formed in our own times in the bowels of the earth, whether in rents and caverns, or by the cooling of lakes of melted lava, we may safely infer that the rocks are heavier and less porous than true lavas, and more crystalline, although composed of the same mineral ingredients. As the hardest crystals produced artificially in the laboratory, require the longest time for their formation, so we must suppose that where the cooling down of melted matter takes place by insensible degrees, in the course of ages a variety of minerals will be produced far harder than any formed by natural processes within the short period of human observation.

These subterranean volcanic rocks, moreover, cannot be stratified in the same manner as sedimentary deposits from water, although it is evident that when great masses consolidate from a state of fusion, they may separate into natural divisions; for this is seen to be the case in many lava-currents. We may also expect that the rocks in question will often be rent by earthquakes, since these are common in volcanic

regions, and the fissures will be often injected with similar matter, so that dikes of crystalline rock will traverse masses of similar composition. It is also clear that no organic remains can be included in such masses, unless where sedimentary strata have subsided to great depths, and in this case the fossil substances will probably be so acted upon by heat, that all signs of organization will be obliterated. Lastly, these deep-seated igneous formations must underlie all the strata containing organic remains, because the heat proceeds from below upwards, and the intensity required to reduce the mineral ingredients to a fluid state must destroy all organic bodies in rocks either subjacent or included in the midst of them.

If, by a continued series of elevatory movements, such masses shall hereafter be brought up to the surface, in the same manner as sedimentary marine strata have, in the course of ages, been upheaved to the summit of the loftiest mountains, it is not difficult to foresee what perplexing problems may be presented to the geologist. He may, then, perhaps, study in some mountain chain the very rocks produced at the depth of several miles beneath the Andes, Iceland, or Java, in the time of Leibnitz, and draw from them the same conclusion which that philosopher derived from certain igneous products of high antiquity; for he conceived our globe to have been, for an indefinite period, in the state of a comet, without an ocean, and uninhabitable alike by aquatic or terrestrial animals.

CHAPTER XXIII.

Earthquakes and their effects—Deficiency of ancient accounts—Ordinary atmospheric phenomena—Changes produced by earthquakes in modern times considered in chronological order—Earthquake in Murcia, 1829—Island of Ischia in 1828—Bogota in 1827—Chili in 1822—Great extent of country elevated—Aleppo in 1822—Ionian Isles in 1820—Island of Sumbawa in 1815—Town of Tomboro submerged—Earthquake of Cutch in 1819—Subsidence of the delta of the Indus—Earthquake of Caraccas in 1812—South Carolina in 1811—Geographical changes in the valley of the Mississippi—Volcanic convulsions in the Aleutian Islands in 1806—Reflections on the earthquakes of the nineteenth century—Earthquake in Quito, 1797—Cumana, 1797—Caraccas, 1790—Sicily, 1790—Java, 1786—Sinking down of large tracts.

EARTHQUAKES AND THEIR EFFECTS.

We have already stated, in our sketch of the geographical boundaries of volcanic regions, that, although the points of eruption are but thinly scattered, and form mere spots on the surface of those vast districts, yet the subterranean movements extend simultaneously over immense areas. We shall now proceed to consider the changes which these movements have been observed to produce on the surface, and in the internal structure of the earth's crust.

Deficiency of ancient accounts.—It is only within the last century and a half, since Hooke first promulgated his views respecting the connexion between geological phenomena and earthquakes, that the permanent changes effected by these convulsions have excited attention. Before that time, the narrative of the historian was almost exclusively confined to the number of human beings who perished, the number of cities laid in ruins, the value of property destroyed, or certain atmospheric appearances which dazzled or terrified the observers. The creation of a new lake, the engulphing of a city, or the raising of a new island, are sometimes, it is true, adverted to, as being too obvious, or of too much geographical interest, to be passed over in silence. But no researches were made ex-

pressly with a view of ascertaining the precise amount of depression or elevation of the ground, or the particular alterations in the relative position of sea and land; and very little distinction was made between the raising of soil by volcanic ejections, and the upheaving of it by forces acting from below. The same remark applies to a very large proportion of modern accounts; and how much reason we have to regret this deficiency of information is apparent from the fact that, in every instance where a spirit of scientific inquiry has animated the eye-witnesses of these events, facts calculated to throw much light on former modifications of the earth's structure have been recorded.

Atmospheric phenomena attending earthquakes.—As we shall confine ourselves almost entirely, in our notice of certain earthquakes, to the changes brought about by them in the configuration of the earth's crust, we may mention, generally, some accompaniments of these terrible events which are almost uniformly commemorated in history, that it may be unnecessary to advert to them again. Irregularities in the seasons preceding or following the shocks; sudden gusts of wind, interrupted by dead calms; violent rains at unusual seasons, or in countries where such phenomena are almost unknown; a reddening of the sun's disk, and a haziness in the air, often continued for months; an evolution of electric matter, or of inflammable gas from the soil, with sulphureous and mephitic vapours; noises underground, like the running of carriages, or the discharge of artillery, or distant thunder; animals uttering cries of distress, and evincing extraordinary alarm, being more sensitive than men of the slightest movement; a sensation like sea-sickness, and a dizziness in the head, experienced by men:—these, and other phenomena which do not immediately bear on our present subject, have recurred again and again at distant ages, and in all parts of the globe.

We shall now begin our enumeration with the latest authentic narratives of earthquakes, and so carry back our survey retrospectively, that we may bring before the reader, in the

first place, the minute and circumstantial details of modern times, and enable him, by observing the extraordinary amount of change within the last hundred and fifty years, to perceive how great must be the deficiency in the meagre annals of earlier eras.

EARTHQUAKES OF THE NINETEENTH CENTURY.

Murcia, 1829.—The first event which presents itself in our chronological order is the earthquake which happened in the south of Spain on the 21st of March, 1829. It appears, by the narrative of M. Cassas, the French consul at Alicant, that the accounts of the catastrophe were generally much exaggerated. The district violently agitated was only about four square miles in area, being the basin of the river Segura, between Orihuela and the sea. All the villages in this tract were thrown down by a vertical movement, the soil being traversed by innumerable crevices four or five inches broad. In the alluvial plain, especially that part near the sea, small circular apertures were formed, out of which black mud, salt water, and marine shells were vomited; and in other places fine yellowish-green micaceous sand, like that on the beach at Alicant, was thrown up in jets. No crater sent forth lava, as was asserted in several Spanish journals *.

Ischia, 1828.—On the 2nd of February the whole island of Ischia was shaken by an earthquake, and in the October following I found all the houses in Casamicciol still without their roofs. On the sides of a ravine between that town and Forio, I saw masses of greenish tuff, which had been thrown down. The hot-spring of Rita, which was nearest the centre of the movement, was ascertained by M. Covelli to have increased in temperature, showing, as he observes, that the explosion took place below the reservoirs which heat the thermal waters †.

Bogota, 1827.—On the 16th of November, 1827, the plain of Bogota was convulsed by an earthquake, and a great number

* Férussac, Bulletin des Sci. Nat., Nov. 1829, p. 203.

† Biblioth. Univ., Oct. 1828, p. 157, and Férussac, Bulletin, &c., tome xi. p. 297.

of towns were thrown down. Torrents of rain swelled the Magdalena, sweeping along vast quantities of mud and other substances, which emitted a sulphureous vapour and destroyed the fish. Popayan, which is distant two hundred geographical miles S. S.W. of Bogota, suffered greatly. Wide crevices appeared in the road of Guanacas, leaving no doubt that the whole of the Cordilleras sustained a powerful shock. Other fissures opened near Costa, in the plains of Bogota, into which the river Tunza immediately began to flow *. In such cases, we may observe, the ancient gravel bed of a river is deserted, and a new one formed at a lower level; so that a want of relation in the position of alluvial beds to the existing water-courses may be no test of the high antiquity of such deposits to a geologist, in countries habitually convulsed by earthquakes. Extraordinary rains accompanied the shocks before mentioned, and two volcanos are said to have been in eruption in the mountain-chain nearest to Bogota.

Chili, 1822.—On the 19th of November, 1822, the coast of Chili was visited by a most destructive earthquake. The shock was felt simultaneously throughout a space of one thousand two hundred miles from north to south. St. Jago, Valparaiso, and some other places, were greatly injured. When the district round Valparaiso was examined on the morning after the shock, it was found that the whole line of coast, for the distance of above one hundred miles, was raised above its former level †. At Valparaiso the elevation was three feet, and at Quintero about four feet. Part of the bed of the sea remained bare and dry at high water, 'with beds of oysters, muscles, and other shells, adhering to the rocks on which they grew, the fish being all dead, and exhaling most offensive effluvia ‡.'

I am informed by Mr. Cruckshanks, who resided in the country during the earthquake, that, for several days after the

* Phil. Mag., July 1828, p. 37.

† See Geol. Trans., vol. i., second series; and also Journ. of Sci., 1824, vol. xvii. p. 40.

‡ Geol. Trans., vol. i., second series, p. 415.

event, fishermen dug out certain burrowing shell-fish from sands *above* low-water mark, which previously they had only procured *below* that level. The same gentleman found that some rocks of greenstone at Quintero, a few hundred yards from the beach, which had always been under water till the shock of 1822, have since been uncovered when the tide is at half-ebb; and he states that, after the earthquake, it was the general belief of the fishermen and inhabitants of the Chilian coast, *not* that the land had risen, but that the ocean had permanently retreated.

An old wreck of a ship, which before could not be approached, became accessible from the land; although its distance from the original sea-shore had not altered. It was observed that the water-course of a mill, at the distance of about a mile from the sea, gained a fall of fourteen inches, in little more than one hundred yards; and from this fact it is inferred that the rise in some parts of the inland country was far more considerable than on the coast *. Part of the coast thus elevated consisted of granite, in which parallel fissures were caused, some of which were traced for a mile and a half inland. Cones of earth, about four feet high, were thrown up in several districts, by the forcing up of water mixed with sand through funnel-shaped hollows—a phenomenon very common in Calabria, and the explanation of which will hereafter be considered. Those houses in Chili, of which the foundations were on rock, were less damaged than such as were built on alluvial soil.

Extent of country elevated.—The area over which this permanent alteration of level extended, was estimated at one hundred thousand square miles. The whole country, from the foot of the Andes to a great distance under the sea, is supposed to have been raised, the greatest rise being at the distance of about two miles from the shore. 'The rise upon the coast was from two to four feet:—at the distance of a mile inland it must have been from five to six, or seven feet †.' The sound-

* Journ. of Sci., vol. xvii. p. 42. † Ibid., pp. 40, 45.

ings in the harbour of Valparaiso have been materially changed by this shock, and the bottom has become shallower. The shocks continued up to the end of September, 1823: even then, forty-eight hours seldom passed without one, and sometimes two or three were felt during twenty-four hours. Mrs. Graham observed, after the earthquake of 1822, that, besides the beach newly raised above high-water mark, there were several older elevated lines of beach one above the other, consisting of shingle mixed with shells, extending in a parallel direction to the shore, to the height of fifty feet above the sea *.

Aleppo, 1822.—In 1822 Aleppo was destroyed by an earthquake, and alterations are said to have been caused in the level of the land; but of these we have no exact details. At the same time two rocks were reported by the captain of a French vessel to have risen from the sea, in the neighbourhood of Cyprus, an island well known to be subject to subterranean movements, and almost under the same latitude as Aleppo †. In these and similar instances, where there is no evidence of a submarine eruption, it is not the magnitude of the masses lifted above the sea which are of importance, but the indication apparently afforded by them, that a submarine tract, of which they merely form the highest points, has undergone some change of level.

Ionian Isles, 1820.—In the year 1820, from the 15th of February to the 6th of March, Santa Maura, one of the Ionian isles, experienced a succession of destructive earthquakes. Immediately afterwards a rocky island was observed not far from the coast, which had never been known before ‡. No indications of a submarine eruption were observed on this spot: it is, therefore, most probable that this rock was elevated by the earthquake; but an examination of its structure is much to be desired.

* Geol. Trans., vol. i., second series, p. 415.

† Journ. of Sci., vol. xiv. p. 450.

‡ Allgemeine Zeitung, 1820, No. 146. Verneul, Journal des Voyages, vol. vi. p. 383; cited by Von Hoff, vol. ii. p. 180.

Island of Sumbawa, 1815.—In April, 1815, one of the most frightful eruptions recorded in history occurred in the mountain Tomboro, in the island of Sumbawa. It began on the 5th of April, and was most violent on the 11th and 12th, and did not entirely cease till July. The sound of the explosions was heard in Sumatra, at the distance of nine hundred and seventy geographical miles in a direct line; and at Ternate in an opposite direction, at the distance of seven hundred and twenty miles. Out of a population of twelve thousand, only twenty-six individuals survived on the island. Violent whirlwinds carried up men, horses, cattle, and whatever else came within their influence, into the air, tore up the largest trees by the roots, and covered the whole sea with floating timber *. Great tracts of land were covered by lava, several streams of which, issuing from the crater of the Tomboro mountain, reached the sea. So heavy was the fall of ashes, that they broke into the Resident's house at Bima, forty miles east of the volcano, and rendered it, as well as many other dwellings in the town, uninhabitable. On the side of Java, the ashes were carried to the distance of three hundred miles, and two hundred and seventeen towards Celebes, in sufficient quantity to darken the air. The floating cinders to the westward of Sumatra formed on the 12th of April a mass two feet thick, and several miles in extent, through which ships with difficulty forced their way.

The darkness occasioned in the daytime by the ashes in Java was so profound, that nothing equal to it was ever witnessed in the darkest night. Although this volcanic dust when it fell was an impalpable powder, it was of considerable weight, when compressed, a pint of it weighing twelve ounces and three-quarters. Along the sea-coast of Sumbawa, and the adjacent isles, the sea rose suddenly to the height of from two to twelve feet, a great wave rushing up the estuaries, and then suddenly subsiding. Although the wind at Bima was still during the whole time, the sea rolled in upon the shore, and filled the

* Raffles's Java, vol. i. p. 28.

lower parts of the houses with water a foot deep. Every prow and boat was forced from the anchorage, and driven on shore.

Town of Tomboro submerged.—On the 19th of April, says one of Raffles's correspondents, 'we grounded on the bank of Bima town. The anchorage at Bima must have altered considerably, as where we grounded the Ternate cruiser lay at anchor in six fathoms a few months before.' Unfortunately no facts are stated by which we may judge with certainty whether this shoal, implying a change of depth of more than thirty feet, was caused by an accumulation of ashes, or by an upheaving of the bottom of the sea. It is stated, however, that the surrounding country was covered with ashes. On the other hand, the town called Tomboro, on the west side of the volcano, was overflowed by the sea, which encroached upon the shore at the foot of the volcano, so that the water remained permanently eighteen feet deep in places where there was land before. Here we may observe, that the amount of subsidence of land was very apparent *in spite of the ashes*, which would naturally have caused the limits of the coast to be extended.

The area over which tremulous noises and other volcanic effects extended, was one thousand English miles in circumference, including the whole of the Molucca islands, Java, a considerable portion of Celebes, Sumatra, and Borneo. In the island of Amboyna, in the same month and year, the ground opened, threw out water, and then closed again *. We may conclude, by reminding the reader, that but for the accidental presence of Sir Stamford Raffles, then governor of Java, we should scarcely have heard in Europe of this tremendous catastrophe. He required all the residents in the various districts under his authority to send in a statement of the circumstances which occurred within their own knowledge; but, valuable as were their communications, they are often calculated to excite rather than to satisfy the curiosity of the geologist. They

* Raffles's Hist. of Java, vol. i. p. 25.—Ed. Phil. Journ., vol. iii. p. 389.

mention, that similar effects, though in a less degree, had about seven years before accompanied an eruption of Carang Assam, a volcano in the island of Bali, west of Sumatra; but no particulars of this catastrophe are recorded *.

Cutch, 1819.—A violent earthquake occurred at Cutch, in the delta of the Indus, on the 16th of June, 1819. The principal town, Bhooi, was converted into a heap of ruins, and its stone buildings thrown down. The shock extended to Ahmedhabad, where it was very destructive; and at Poonah, four hundred miles farther, it was feebly felt. At the former city, the great mosque erected by Sultan Ahmed nearly four hundred and fifty years before, fell to the ground, attesting how long a period had elapsed since a shock of similar violence had visited that point. At Anjar, the fort, with its tower and guns, were hurled to the ground in one common mass of ruin. The shocks continued some days until the 20th, when, thirty miles from Bhooi, a volcano burst out in eruption, and the convulsions ceased.

Subsidence in the Delta of the Indus.—Although the ruin of towns was great, the face of Nature in the inland country, says Captain Macmurdo, was not visibly altered. In the hills some large masses only of rock and soil were detached from the precipices; but the eastern and almost deserted channel of the Indus, which bounds the province of Cutch, was greatly changed. This estuary or inlet of the sea was, before the earthquake, fordable at Luckput, being only about a foot deep when the tide was at ebb, and at flood tide never more than six feet; but it was deepened at the fort of Luckput, after the shock, to more than *eighteen feet at low water* †. On sounding other parts of the channel, it was found, that where previously the depth of the water at flood never exceeded one or two feet, it had become from four to ten feet deep; and this increase of depth extended from Cutch to the Sindh shore, a distance of three or four miles. The channel of the Runn,

* Life and Services of Sir Stamford Raffles, p. 241. London, 1830.

† Ed. Phil. Journ., vol. iv. p. 106.

which extends from Luckput round the north of the province of Cutch, was sunk so much, that, instead of being dry as before during that period of the year, it was no longer fordable except at one spot only. By these remarkable changes of level, a part of the inland navigation of that country, which had been closed for centuries, became again practicable.

Fort and Village submerged.—The fort and village of Sindree, situated where the Runn joins the Indus, are stated by the same writer to have been overflowed; and, after the shock, the tops of the houses and wall were alone to be seen above the water, for the houses, although submerged, were not cast down. Had they been situated, therefore, in the interior, where so many forts were levelled to the ground, their site would, perhaps, have been regarded as having remained comparatively unmoved. Hence we are inclined to suspect that great permanent upheavings and depressions of soil may be the result of earthquakes, without the inhabitants being in the least degree conscious of any change of level.

A more recent survey of Cutch by Lieutenant A. Burnes, confirms the facts above enumerated, and adds many important details *. That officer examined the delta of the Indus in 1826 and 1829, and from his account it appears that the tract around Sindree, which subsided during the earthquake in June 1819, was converted from dry land into sea in the course of a few hours, the new-formed mere extending for a distance of sixteen miles on each side of the fort, and probably exceeding in area the Lake of Geneva. Neither the rush of the sea into this new depression, nor the movement of the earthquake, threw down the small fort of Sindree, the interior of which is said to have become *a tank*, the water filling the space within the walls, and the four towers continuing to stand, so that on the day after the earthquake the people in the fort, who had ascended to the top of one of the towers, saved themselves in boats.

Elevation of the Ullah Bund.—Immediately after the shock

* This Memoir is now in the Library of the Royal Asiatic Society of London.

the inhabitants of Sindree saw, at the distance of five miles from their village, a long elevated mound where previously there had been a low and perfectly level plain. To this uplifted tract they gave the name of 'Ullah Bund,' or the 'Mound of God,' to distinguish it from an artificial barrier previously thrown across an arm of the Indus.

Extent of country raised.—It is already ascertained that this new-raised country is *upwards of fifty miles* in length from east to west, running parallel to that line of subsidence before mentioned, which caused the grounds around Sindree to be flooded. The range of this elevation extends from Puchum island towards Gharee; its breadth from north to south is conjectured to be in some parts *sixteen miles*, and its greatest ascertained height above the original level of the delta is ten feet, an elevation which appears to the eye to be very uniform throughout.

For several years after the convulsion of 1819 the course of the Indus was very unsettled, and at length in 1826, the river burst its banks above Sinde, and, forcing its way in a more direct course to the sea, cut right through the 'Ullah Bund,' whereby a natural section was obtained. In the perpendicular cliffs thus laid open, Lieutenant Burnes found that the upraised lands consisted of beds of clay filled with shells. The new channel of the river where it intersected the 'bund' was eighteen feet deep, and during the swells in 1826 it was two or three hundred yards in width; but in 1828 the channel was still further enlarged. The Indus, when it first opened this new passage, threw such a body of water into the new lake or salt lagoon of Sindree that it became fresh for many months; but it had recovered its saltness in 1828, when the supply of river water was less copious, and finally it became more salt than the sea, in consequence, as the natives suggested to Lieutenant Burnes, of the saline particles with which the 'Runn of Cutch' is impregnated.

Besides 'Ullah Bund,' there appears to have been another elevation south of Sindree parallel to that before mentioned,

respecting which, however, no exact information has yet been communicated. There is a tradition of an earthquake which about three centuries before upheaved a large area of the bed of the sea, and converted it into land, in the district now called the 'Runn,' so that numerous harbours were laid dry, and ships were wrecked and engulphed; in confirmation of which account it was observed in 1819, that in the jets of black muddy water thrown out of fissures in that region, there were cast up numerous pieces of wrought iron and ship nails *. Cones of sand six or eight feet in height are said to have been thrown up on these lands †.

We must not conclude without alluding to a *moral* phenomenon connected with this tremendous catastrophe, which we regard as highly deserving the attention of geologists. It is stated by Lieutenant Burnes, that 'these wonderful events passed *unheeded* by the inhabitants of Cutch;' for the region convulsed, though once fertile, had for a long period been reduced to sterility by want of irrigation, so that the natives were indifferent as to its fate. Now it is to this profound apathy which all but highly civilized nations feel, in regard to physical events not having an immediate influence on their worldly fortunes, that we must ascribe the extraordinary dearth of historical information concerning changes of the earth's surface, which modern observations show to be by no means of rare occurrence in the ordinary course of nature.

To the east of the line of this earthquake lies Oojain (called Ozene in the *Peryplus Maris Erythr*). Ruins of an ancient city are there found, a mile north of the present, buried in the earth to the depth of from fifteen to sixteen feet, which inhumation is known to have been the consequence of a tremendous catastrophe in the time of the Rajah Vicramaditya ‡.

Caraccas, 1812.—On the 26th of March, 1812, several violent shocks of an earthquake were felt in Caraccas. The

* Lieutenant Burnes's Account.

† Captain Macmurdo's Memoir, Ed. Phil. Journ. vol. iv., p. 106.

‡ Hoff, vol. ii. p. 454; for further particulars, see vol. ii., chap. xiv.

surface undulated like a boiling liquid, and terrific sounds were heard underground. The whole city with its splendid churches was in an instant a heap of ruins, under which ten thousand of the inhabitants were buried. On the 5th of April, enormous rocks were detached from the mountains. It was believed that the mountain Silla lost from three hundred to three hundred and sixty feet of its height by subsidence; but this was an opinion not founded on any measurement. On the 27th of April, a volcano in St. Vincent's threw out ashes; and on the 30th, lava flowed from its crater into the sea, while its explosions were heard at a distance equal to that between Vesuvius and Switzerland, the sound being transmitted, as Humboldt supposes, through the ground. During the earthquake which destroyed Caraccas, an immense quantity of water was thrown out at Valecillo, near Valencia, as also at Porto Cabello, through openings in the earth; and in the Lake Maracaybo the water sank *.

Although the great change of level in the mountain Silla was not distinctly proved, the opinion of the inhabitants deserves attention, because we shall afterwards have to mention some well-authenticated alterations in the same district during preceding earthquakes. Humboldt observed that the Cordilleras, composed of gneiss and mica slate, and the country immediately at their foot, were more violently shaken than the plains.

South Carolina, 1811—*New Madrid.*—Previous to the destruction of Laguira and Caraccas in 1811, South Carolina was convulsed by earthquakes, and the shocks continued till those cities were destroyed. The valley also of the Mississippi, from the village of New Madrid to the mouth of the Ohio in one direction, and to the St. Francis in another, was convulsed to such a degree as to create lakes and islands. Flint, the geographer, who visited the country seven years after the event, informs us, that a tract of many miles in extent, near

* Humboldt's Pers. Nar., vol. iv., p. 12; and Ed. Phil. Journ., vol. i., p. 272. 1819.

the Little Prairie, became covered with water three or four feet deep; and when the water disappeared, a stratum of sand was left in its place. Large lakes of twenty miles in extent were formed in the course of an hour, and others were drained. The grave-yard at New Madrid was precipitated into the bed of the Mississippi; and it is stated that the ground whereon the town is built has sunk eight feet below its former level *.

The inhabitants relate that the earth rose in great undulations; and when these reached a certain fearful height, the soil burst, and vast volumes of water, sand, and pit-coal, were discharged as high as the tops of the trees. Flint saw hundreds of these deep chasms remaining in an alluvial soil, seven years after. The people in the country, although inexperienced in such convulsions, had remarked that the chasms in the earth were in a direction from S.W. to N.E.; and they accordingly felled the tallest trees, and, laying them at right angles to the chasms, stationed themselves upon them. By this invention, when chasms opened more than once under these trees, several persons were prevented from being swallowed up †. At one period during this earthquake, the ground not far below New Madrid swelled up so as to arrest the Mississippi in its course, and to cause a temporary reflux of its waves. The motion of some of the shocks was horizontal, and of others perpendicular; and the vertical movement is said to have been much less desolating than the horizontal. If this be often the case, those shocks which injure cities least may often produce the greatest alteration of level.

Aleutian Islands, 1806.—In the year 1806, a new island, in the form of a peak, with some low conical hills upon it, rose from the sea among the Aleutian Islands, north of Kamtschatka. According to Langsdorf ‡, it was four geographical miles in circumference; and Von Buch infers from its magnitude, and from its not having again subsided below the level

* Cramer's 'Navigator,' p. 243. Pittsburgh, 1821.

† Silliman's Journ., Jan., 1829.

‡ Bemerkungen auf einer Reise um die Welt., bd. ii. s. 209.

of the sea, that it did not consist merely of ejected matter, like Monte Nuovo, but of solid rock upheaved *. Another extraordinary eruption happened in the spring of the year 1814, in the sea near Unalaschka, in the same archipelago. A new isle was then produced of considerable size, and with a peak three thousand feet high, which remained standing for a year afterwards, though with somewhat diminished height.

Although it is not improbable that the earthquakes accompanying the tremendous eruptions above mentioned may have heaved up part of the bed of the sea, yet we must wait for fuller information before we assume this as a fact. The circumstance of these islands not having disappeared like Sabrina, may have arisen from the emission of lava. If Jorullo, for example, in 1759, had risen from a shallow sea to the height of one thousand six hundred feet, instead of attaining that elevation above the Mexican plateau, the massive current of basaltic lava which poured out from its crater would have enabled it to withstand, for a long period, the action of a turbulent sea.

Reflections on the Earthquakes of the nineteenth century.—We are now about to pass on to the events of the eighteenth century; but, before we leave the consideration of those already enumerated, let us pause for a moment, and reflect how many remarkable facts of geological interest are afforded by the earthquakes above described, though they constitute but a small part of the convulsions even of the last thirty years. New rocks have risen from the waters; the temperature of a thermal spring has been raised; the coast of Chili for one hundred miles has been permanently elevated; a considerable tract in the delta of the Indus has sunk down, and some of its shallow channels have become navigable; an adjoining part of the same district, upwards of fifty miles in length and sixteen in breadth, has been raised about ten feet above its former level; the town of Tomboro has been submerged, and twelve thousand of the inhabitants of Sumbawa have been destroyed. Yet,

* Neue Allgem. Geogr. Ephemer. bd. iii, s. 348.

with a knowledge of these terrific catastrophes, witnessed during so brief a period by the present generation, will the geologist declare with perfect composure that the earth has at length settled into a state of repose? Will he continue to assert that the changes of relative level of land and sea, so common in former ages of the world, have now ceased? If, in the face of so many striking facts, he persists in maintaining this favourite dogma, it is in vain to hope that, by accumulating the proofs of similar convulsions during a series of antecedent ages, we shall shake his tenacity of purpose,

> Si fractus illabatur orbis
> Impavidum ferient ruinæ.

EARTHQUAKES OF THE EIGHTEENTH CENTURY.

Quito, 1797.—On the morning of February 4th, 1797, the volcano of Tunguragua in Quito, and the surrounding district, for forty leagues, from south to north, and twenty leagues from west to east, experienced an undulating movement, which lasted four minutes. The same shock was felt over a tract of one hundred and seventy leagues from south to north, from Piura to Popayan; and one hundred and forty from west to east, from the sea to the river Napo. In the smaller district, first mentioned, every town was levelled to the ground; and Riobamba, Quero, and other places, were buried under masses detached from the mountains. At the foot of Tunguragua the earth was rent open in several places; and streams of water and fetid mud, called 'moya,' poured out, overflowing and wasting everything. In valleys one thousand feet broad, the water of these floods reached to the height of six hundred feet; and the mud deposit barred up the course of the river, so as to form lakes, which in some places continued for more than eighty days. Flames and suffocating vapours escaped from the lake Quilotoa, and killed all the cattle on its shores. The shocks continued all February and March, and on the 5th of April they recurred with almost as much violence as at first. We are told that the form of the surface in the district most shaken

was entirely altered, but no exact measurements are given whereby we may estimate the degree of elevation or subsidence*. Indeed, it would be difficult, except in the immediate neighbourhood of the sea, to obtain any certain standard of comparison, if the levels were really as much altered as the narrations seem to imply.

Cumana, 1797.—In the same year, on the 14th of December, the small Antilles experienced subterranean movements, and four-fifths of the town of Cumana was shaken down by a vertical shock. The form of the shoal of Mornerouge, at the mouth of the river Bourdones, was changed by an upheaving of the ground †.

Caraccas, 1790.—In the Caraccas, near where the Caura joins the Orinoco, between the towns San Pedro de Alcantara and San Francisco de Aripao, an earthquake on St. Matthew's day, 1790, caused a sinking in of the granitic soil, and left a lake eight hundred yards in diameter, and from eighty to one hundred in depth. It was a portion of the forest of Aripao which subsided, and the trees remained green for several months under water ‡.

Sicily, 1790.—On the 18th of March in the same year, at S. Maria di Niscemi, some miles from Terranuova, near the south coast of Sicily, the ground gradually sunk down for a circumference of three Italian miles, during seven shocks; and, in one place, to the depth of thirty feet. It continued to subside to the end of the month. Several fissures sent forth sulphur, petroleum, steam, and hot water; and a stream of mud which flowed for two hours, and covered a space sixty feet long, and thirty broad. This happened far from both the ancient and modern volcanic district, in a group of strata, consisting chiefly of blue clay §.

Java, 1786.—About the year 1786 an earthquake was felt

* Cavanilles, Journ. de Phys., tome xlix. p. 230. Gilberts, Annalen, bd. vi. p. 67. Humboldt's Voy., p. 317.

† Humboldt's Voy., Relat. Hist., part i. p. 309.

‡ Ibid., part ii. p. 632.

§ Ferrara, Campi. fl., p. 51.

at intervals, for the period of four months, in the neighbourhood of Batur, in Java, and an eruption followed. Various rents were formed which emitted a sulphureous vapour; separate tracts sunk away, and were swallowed by the earth. Into one of these the rivulet Dotog entered, and afterwards continued to follow a subterraneous course. The village of Jampang was buried in the ground, with thirty-eight of its inhabitants, who had not time to escape. We are indebted to Dr. Horsfield for having verified the above-mentioned facts *.

Japan Isles, 1783.—In the province of Sinano, in the Isle of Nifon, the volcanic mountain of Asama-yama, situated north-east of the town of Komoro, was in violent eruption August 1, 1783. The eruption was preceded by a frightful earthquake; gulphs are said to have opened everywhere, and many towns to have been swallowed up, while others were subsequently buried by lava †.

* Batav. Trans., vol. viii. p. 141.

† Humboldt, Fragmens Asiatiques, &c., tom. i. p. 229.

CHAPTER XXIV.

Earthquake in Calabria, February 5th, 1783—Shocks continued to the end of the year 1786—Authorities—Extent of the area convulsed—Geological structure of the district—Difficulty of ascertaining changes of relative level even on the sea-coast—Subsidence of the quay at Messina—Shift or fault in the Round Tower of Terranuova—Movement in the stones of two obelisks—Alternate opening and closing of fissures—Cause of this phenomenon—Large edifices engulphed—Dimensions of new caverns and fissures—Gradual closing in of rents—Bounding of detached masses into the air—Landslips—Buildings transported entire to great distances—Formation of fifty new lakes—Currents of mud—Small funnel-shaped hollows in alluvial plains—Fall of cliffs along the sea-coast—Shore near Scilla inundated—State of Stromboli and Etna during the shocks—Illustration afforded by this earthquake of the mode in which valleys are formed.

EARTHQUAKE IN CALABRIA, 1783.

Duration of the shocks.—Of the numerous earthquakes which have occurred in different parts of the globe, during the last hundred years, that of Calabria, in 1783, is the only one of which the geologist can be said to have such a circumstantial account as to enable him fully to appreciate the changes which this cause is capable of producing in the lapse of ages. The shocks began in February, 1783, and lasted for nearly four years, to the end of 1786. Neither in duration, nor in violence, nor in the extent of territory moved, was this convulsion remarkable, when contrasted with many experienced in other countries, both during the last and present century; nor were the alterations which it occasioned in the relative level of hill and valley, land and sea, so great as those effected by some subterranean movements in South America, in our own times. The importance of the earthquake in question arises from the circumstance, that Calabria is the only spot hitherto visited, both during and after the convulsions, by men possessing sufficient leisure, zeal, and scientific information, to enable them to

collect and describe with accuracy the physical facts which throw light on geological questions.

Authorities.—Among the numerous authorities, Vivenzio, physician to the King of Naples, transmitted to the court a regular statement of his observations during the continuance of the shocks; and his narrative is drawn up with care and clearness *. Francesco Antonio Grimaldi, then secretary of war, visited the different provinces at the king's command, and published a most detailed description of the permanent changes in the surface †. He measured the length, breadth and depth of the different fissures and gulphs which opened, and ascertained their number in many provinces. His comments, moreover, on the reports of the inhabitants, and his explanations of their relations, are judicious and instructive. Pignataro, a physician residing at Monteleone, a town placed in the very centre of the convulsions, kept a register of the shocks, distinguishing them into four classes, according to their degree of violence. From his work, it appears that, in the year 1783, the number was nine hundred and forty-nine, of which five hundred and one were shocks of the first degree of force; and in the following year there were one hundred and fifty-one, of which ninety-eight were of the first magnitude.

Count Ippolito, also, and many others, wrote descriptions of the earthquake; and the Royal Academy of Naples, not satisfied with these and other observations, sent a deputation from their own body into Calabria, before the shocks had ceased, who were accompanied by artists instructed to illustrate by drawings the physical changes of the district, and the state of ruined towns and edifices. Unfortunately these artists were not very successful in their representations of the condition of the country, particularly when they attempted to express, on a large scale, the extraordinary revolutions which many of the great and minor river-courses underwent. But many of the plates published by the Academy are valuable; and we shall

* Istoria de' Tremuoti della Calabria, del 1783.

† Descriz. de' Tremuoti Accad. nelle Calabria nel 1783. Napoli, 1784.

frequently avail ourselves of them to illustrate the facts about to be described *.

In addition to these Neapolitan sources of information, our countryman, Sir William Hamilton, surveyed the district, not without some personal risk, before the shocks had ceased; and his sketch, published in the Philosophical Transactions, supplies many facts that would otherwise have been lost. He has explained in a rational manner many events which, as related in the language of some eye-witnesses, appeared marvellous and incredible. Dolomieu also examined Calabria soon after the catastrophe, and wrote an account of the earthquake, correcting a mistake into which Hamilton had fallen, who supposed that a part of the tract shaken had consisted of volcanic tuff. It is indeed a circumstance which enhances the geological interest of the commotions which so often modify the surface of Calabria, that they are confined to a country where there are neither ancient nor modern rocks of igneous origin; so that at some future time, when the era of disturbance shall have passed by, the cause of former revolutions will be as latent as in parts of Great Britain now occupied exclusively by ancient marine formations.

Extent of the area convulsed.—The convulsion of the earth, sea, and air, extended over the whole of Calabria Ultra, the south-east part of Calabria Citra, and across the sea to Messina and its environs—a district lying between the 38th and 39th degrees of latitude. The concussion was perceptible over a great part of Sicily, and as far north as Naples; but the surface over which the shocks acted so forcibly as to excite intense alarm did not generally exceed five hundred square miles in circumference. The soil of that part of Calabria is composed chiefly, like the southern part of Sicily, of calcareo-argillaceous strata of great thickness, containing marine shells. This clay is sometimes associated with beds of sand and limestone. For the most part these formations resemble in appearance and

* Istoria de' Fenomeni del Tremoto, &c., nell' an. 1783, posta in luce dalla Real. Accad., &c., di Nap. Napoli, 1784, fol.

consistency the Subapennine marls, with their accompanying sands and sandstones; and the whole group bears considerable resemblance, in the yielding nature of its materials, to most of our tertiary deposits in France and England. Chronologically considered, however, the Calabrian formations are comparatively of very modern date, and abound in fossil shells referrible to species now living in the Mediterranean.

We learn from Vivenzio that, on the 20th and 26th of March, 1783, earthquakes occurred in the islands of Zante, Cephalonia, and St. Maura; and in the last-mentioned isle several public edifices and private houses were overthrown, and many people destroyed. We have already shown that the Ionian Isles fall within the line of the same great volcanic region as Calabria; so that both earthquakes were probably derived from a common source, and it is not improbable that the bed of the whole intermediate sea was convulsed.

If the city of Oppido, in Calabria, be taken as a centre, and round that centre a circle be described with a radius of twenty-two miles, this space will comprehend the surface of the country which suffered the greatest alteration, and where all the towns and villages were destroyed. But if we describe the circle with a radius of seventy-two miles, this will then comprehend the whole country that had any permanent marks of having been affected by the earthquake. The first shock, of February 5th, 1783, threw down in two minutes the greater part of the houses in all the cities, towns, and villages, from the western flanks of the Apennines in Calabria Ultra, to Messina in Sicily, and convulsed the whole surface of the country. Another occurred on the 28th of March, with almost equal violence. The granitic chain which passes through Calabria from north to south, and attains the height of many thousand feet, was shaken but slightly; but it is said that a great part of the shocks which were propagated with a wave-like motion through the recent strata, from west to east, became very violent when they reached the point of junction with the granite, as if a reaction was produced where the undulatory movement

of the soft strata was suddenly arrested by the more solid rocks. The surface of the country often heaved like the billows of a swelling sea, which produced a swimming in the head like sea-sickness. It is particularly stated, in almost all the accounts, that just before each shock the clouds appeared motionless; and, although no explanation is offered of this phenomenon, it is obviously the same as that observed in a ship at sea when it pitches violently. The clouds seem arrested in their career as often as the vessel rises in a direction contrary to their course; so that the Calabrians must have experienced precisely the same motion on the land.

We shall first consider that class of physical changes produced by the earthquake, which are connected with changes in the relative level of the different parts of the land; and afterwards describe those which are more immediately connected with the derangement of the regular drainage of the country, and where the force of running water co-operated with that of the earthquake.

Difficulty of ascertaining changes of level.—In regard to alterations of relative level, none of the accounts establish that they were on a considerable scale; but it must always be remembered that, in proportion to the area moved is the difficulty of proving that the general level has undergone any change, unless the sea-coast happens to have participated in the principal movement. Even then it is often impossible to determine whether an elevation or depression even of several feet has occurred, because there is nothing novel in a band of sand and shingle of unequal breadth above the level of the sea running parallel to a coast, such bands generally marking the point reached by the waves during spring tides or the most violent tempests. The scientific investigator has not sufficient topographical knowledge to discover whether the extent of beach has diminished or increased; and he who has the necessary local information scarcely ever feels any interest in ascertaining the amount of the rise or fall of the ground. Add to this the great difficulty of making correct observations, in consequence

of the enormous waves which roll in upon a coast during an earthquake, and efface every landmark near the shore.

Subsidence of the Quay at Messina.—It is evidently in seaports alone that we can look for very accurate indications of slight changes of level; and when we find them, we may presume that they would not be rare at other points, if equal facilities of comparing relative altitudes were afforded. Grimaldi states (and his account is confirmed by Hamilton and others) that at Messina in Sicily the shore was rent; and the soil along the port, which before the shock was perfectly level, was found afterwards to be inclined towards the sea, the sea itself near the 'Banchina' becoming deeper, and its bottom in several places disordered. The quay also sank down about fourteen inches below the level of the sea, and the houses in its vicinity were much fissured *.

Among various proofs of partial elevation and depression in the interior, the Academicians mention, in their Survey, that the ground was sometimes on the same level on both sides of new ravines and fissures, but sometimes there had been a considerable shifting, either by the upheaving of one side or the subsidence of the other. Thus, on the sides of long rents in the territory of Soriano, the stratified masses had altered their

No. 19.

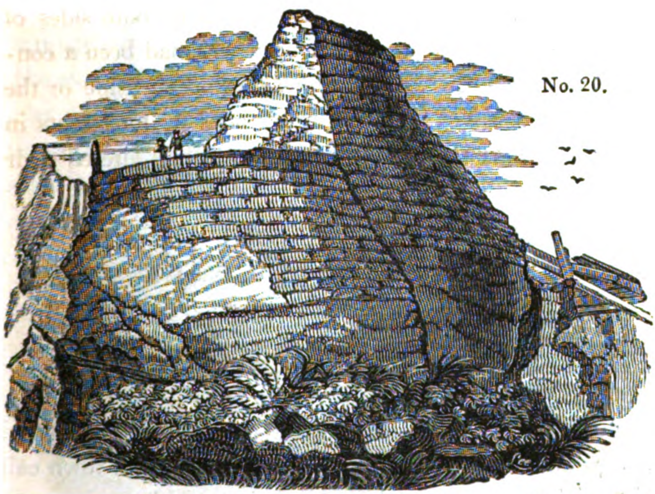
Deep fissure near Polistena, caused by the earthquake of 1783.

* Phil. Trans., 1783.

relative position to the extent of from eight to fourteen palms (six to ten and a half feet).

Polistena.—Similar shifts in the strata are alluded to in the territory of Polistena, where there appeared innumerable fissures in the earth. One of these was of great length and depth; and in parts the level of the corresponding sides was greatly changed. (See wood-cut No. 19.)

Terranuova.—In the town of Terranuova some houses were seen uplifted above the common level, and others adjoining sunk down into the earth. In several streets the soil appeared thrust up, and abutted against the walls of houses; a large circular tower of solid masonry, which had withstood the general destruction, was divided by a vertical rent, and one side was upraised, and the foundations heaved out of the ground. It was compared by the Academicians to a great tooth half extracted from the alveolus, with the upper part of the fangs exposed. (See cut No. 20.)



No. 20.

Shift or 'fault' in the round tower of Terranuova in Calabria, occasioned by the earthquake of 1783.

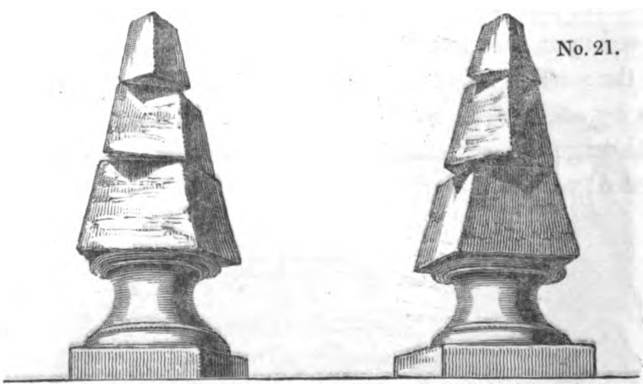
Along the line of this shift, or 'fault' as it would be termed technically by miners, the walls were found to adhere firmly to each other, and to fit so well, that the only signs of their

having been disunited was the want of correspondence in the courses of stone on either side of the rent.

In some walls which had been thrown down, or violently shaken, in Monteleone, the separate stones were parted from the mortar, so as to leave an exact mould where they had rested, whereas in other cases the mortar was ground to dust between the stones.

It appears that the wave-like motions, and those which are called vorticose or whirling in a vortex, often produced effects of the most capricious kind. Thus, in some streets of Monteleone, every house was thrown down but one; in others, all but two; and the buildings which were spared were often scarcely in the least degree injured.

In many cities of Calabria, all the most solid buildings were thrown down, while those which were slightly built, escaped; but at Rosarno, as also at Messina, in Sicily, it was precisely the reverse, the massive edifices being the only ones that stood.



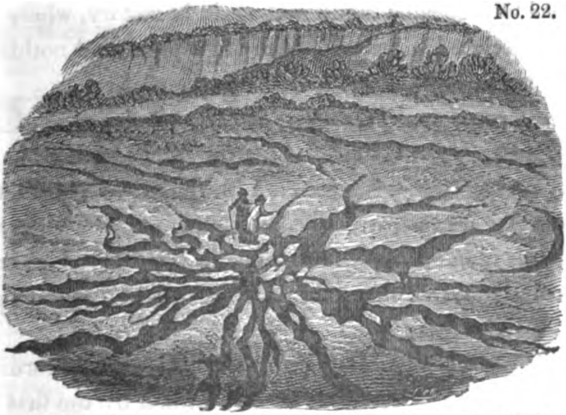
Shift in the stones of two obelisks in the Convent of S. Bruno.

Two obelisks (No. 21) placed at the extremities of a magnificent façade in the convent of S. Bruno, in a small town called Stefano del Bosco, were observed to have undergone a movement of a singular kind. The shock which agitated the building is described as having been horizontal and vorticose. The pedestal of each obelisk remained in its original place; but the separate stones above were turned partially round, and re-

moved sometimes nine inches from their position, without falling.

Fissures.—It appears evident that a great part of the rending and fissuring of the ground was the effect of a violent motion from below upwards; and in a multitude of cases where the rents and chasms opened and closed alternately, we must suppose that the earth was by turns heaved up, and then let fall again. We may conceive the same effect to be produced on a small scale, if, by some mechanical force, a pavement composed of large flags of stone should be raised up and then allowed to fall suddenly, so as to resume its original position. If any small pebbles happened to be lying on the line of contact of two flags, they would fall into the opening when the pavement rose, and be swallowed up, so that no trace of them would appear after the subsidence of the stones. In the same manner, when the earth was upheaved, large houses, trees, cattle, and men were engulphed in an instant in chasms and fissures; and when the ground sank down again, the earth closed upon them, so that no vestige of them was discoverable on the surface. In many instances, individuals were swallowed up by one shock, and then thrown out again alive, together with large jets of water, by the shock which immediately succeeded.

No. 22.



Fissures near Jerocarné, in Calabria, caused by the earthquake of 1783.

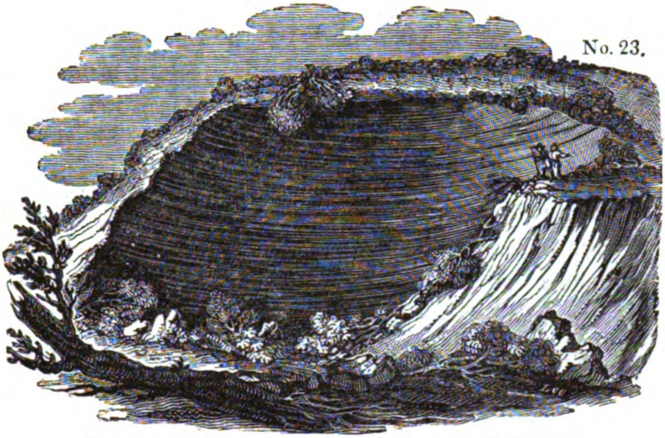
At Jerocarne, a country which, according to the Academicians, was *lacerated* in a most extraordinary manner, the fissures ran in every direction like cracks on a broken pane of glass (see cut No. 22); and as a great portion of them remained open after the shocks, it is very possible that this country was permanently upraised.

Houses engulphed.—In the vicinity of Oppido, the central point from which the earthquake diffused its violent movements, many houses were swallowed up by the yawning earth, which closed immediately over them. In the adjacent district also of Cannamaria, four farm-houses, several oil-stores, and some spacious dwelling-houses were so completely engulphed in one chasm, that not a vestige of them was afterwards discernible. The same phenomenon occurred at Terranuova, S. Christina, and Sinopoli. The Academicians state particularly that when deep abysses had opened in the argillaceous strata of Terranuova, and houses had sunk into them, the sides of the chasms closed with such violence that, on excavating afterwards to recover articles of value, the workmen found the contents and detached parts of the buildings jammed together so as to become one compact mass. It is unnecessary to accumulate examples of similar occurrences; but so many are well authenticated during this earthquake in Calabria, that we may, without hesitation, yield assent to the accounts of catastrophes of the same kind repeated again and again in history, where whole towns are declared to be have been engulphed, and nothing but a pool of water or tract of sand left in their place.

Chasm formed near Oppido.—On the sloping side of a hill near Oppido, a great chasm opened, and, although a large quantity of soil was precipitated into the abyss, together with a considerable number of olive-trees and part of a vineyard, a great gulph remained after the shock in the form of an amphitheatre, five hundred feet long and two hundred feet deep (see cut No. 23).

Dimensions of new Fissures and Chasms.—According to Grimaldi, many fissures and chasms, formed by the first shock of February 5th, were greatly widened, lengthened, and deep-

No. 23.



Chasm formed by the earthquake of 1783, near Oppido, in Calabria.

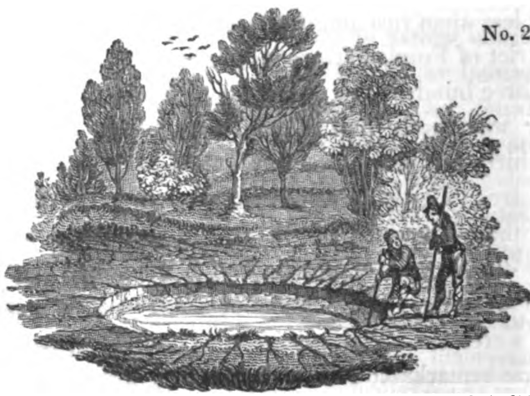
ened by the violent convulsions of March 28th. In the territory of San Fili, this observer found a new ravine, half a mile in length, two feet and a half broad, and twenty-five feet deep; and another of similar dimensions in the territory of Rosarno. A ravine *nearly a mile long, one hundred and five feet broad,* and thirty feet deep, opened in the district of Plaisano, where, also, two gulphs were caused—one in a place called Cerzulle, three-quarters of a mile long, *one hundred and fifty feet broad,* and above *one hundred feet deep,* and another at La Fortuna, nearly a quarter of a mile long, above thirty feet in breadth, and no less than *two hundred and twenty-five feet deep.* In the district of Fosolano three gulphs opened: one of these measured three hundred feet square, and above thirty feet deep; another was nearly half a mile long, fifteen feet broad, and above thirty feet deep; the third was seven hundred and fifty feet square. Lastly, a calcareous mountain, called Zefirio, at the southern extremity of the Italian peninsula, was cleft in two for the length of nearly half a mile, and an irregular breadth of many feet. Some of these chasms were in the form of a crescent. The annexed cut (No. 24) represents one by no means remarkable for its dimensions, which remained open by the side of a small pass over the hill of St. Angelo, near Soriano. The small river Mesima is seen in the foreground.

No. 24.

Chasm in the hill of St. Angelo, near Soriano, in Calabria, caused by the earthquake of 1783.

Formation of new lakes.—In the vicinity of Seminara, a lake was suddenly formed by the opening of a great chasm, from the bottom of which water issued. This lake was called Lago del Tolfilo. It extended 2380 palms in length, by 1250 in breadth, and 70 in depth. The inhabitants, dreading the miasma of this stagnant pool, endeavoured, at great cost, to drain it by canals, but without success, as it was fed by springs issuing from the bottom of the deep chasm. A small circular subsidence occurred not far from Polistena, of which a representation is given in the annexed cut.

No. 25.



Circular pond near Polistena, in Calabria, caused by the earthquake in 1783.

Gradual closing in of fissures.—Sir W. Hamilton was shown

several deep fissures in the vicinity of Mileto, which, although not one of them was above a foot in breadth, had opened so wide during the earthquake as to swallow up an ox and near one hundred goats. The Academicians also found, on their return through districts which they had passed at the commencement of their tour, that many rents had in that short interval gradually closed in, so that their width had diminished several feet, and the opposite walls had sometimes nearly met. It is natural that this should happen in argillaceous strata, while in more solid rocks we may expect that fissures will remain open for ages. Should this be ascertained to be a general fact in countries convulsed by earthquakes, it would afford a satisfactory explanation of a common phenomenon in mineral veins. Such veins often retain their full size so long as the rocks consist of limestone, granite, or other indurated materials; but they contract their dimensions, become mere threads, or are even entirely cut off, where masses of an argillaceous nature are interposed. If we suppose the filling up of fissures with metallic and other ingredients to be a process requiring ages for its completion, it is obvious that the opposite walls of rents, where strata consist of yielding materials, must collapse or approach very near to each other before sufficient time is allowed for the accretion of a large quantity of veinstone.

Thermal waters augmented.—It is stated by Grimaldi that the thermal waters of St. Euphemia, in Terra di Amato, which first burst out during the earthquake of 1638, acquired, in February, 1783, an augmentation both in quantity and degree of heat. This fact appears to indicate a connexion between the heat of the interior and the fissures caused by the Calabrian earthquakes, notwithstanding the absence of volcanic rocks either ancient or modern in that district.

Bounding of detached masses into the air.—The violence of the movement of the ground upwards was singularly illustrated by what the Academicians call the 'sbalzo,' or bounding into the air, to the height of several yards, of masses slightly adher-

ing to the surface. In some towns a great part of the pavement-stones were thrown up, and found lying with their lower sides uppermost. In these cases we must suppose that they were propelled upwards by the momentum which they had acquired, and that the adhesion of one end of the mass being greater than that of the other, a rotatory motion had been communicated to them. When the stone was projected to a sufficient height to perform somewhat more than a quarter of a revolution in the air, it pitched down on its edge and fell with its lower side uppermost.

Effects of earthquakes on the excavation of valleys.—The next class of effects to be considered, are those more immediately connected with the formation of valleys, in which the action of water was often combined with that of the earthquake. The country agitated was composed, as we before stated, chiefly of argillaceous strata, intersected by deep narrow valleys, sometimes from five to six hundred feet deep. As the boundary cliffs were in great part vertical, it will readily be conceived that, amidst the various movements of the earth, the precipices overhanging the rivers, being without support on one side, were often thrown down. We find, indeed, that inundations produced by obstructions in river-courses are among the most disastrous consequences of great earthquakes in all parts of the world; for the alluvial plains in the bottoms of valleys are usually the most fertile and well peopled parts of the whole country, and whether the site of a town is above or below a temporary barrier in the channel of a river, it is exposed to injury by the waters either of a lake or a flood.

Landslips.—From each side of the deep valley or ravine of Terranuova, enormous masses of the adjoining flat country were detached and cast down into the course of the river, so as to give rise to great lakes. Oaks, olive-trees, vineyards, and corn, were often seen growing at the bottom of the ravine, as little injured as their companions from which they were separated in the plain above at least five hundred feet higher, and

at the distance of about three-quarters of a mile. In one part of this ravine was an enormous mass, two hundred feet high, and about four hundred feet in diameter at its base, which had been detached by some former earthquake. It is well attested that this mass travelled down the ravine nearly four miles, having been put in motion by the earthquake of the 5th of February. Hamilton, after examining the locality, declared that this phenomenon might be accounted for by the declivity of the valley, the great abundance of rain which fell, and the great weight of the alluvial matter which pressed behind it. The momentum of the 'terre movitine,' or lavas, as the flowing mud is called in the country, is no doubt very great; but the transportation of masses that might be compared to small hills, for a distance of several miles at a time, is an effect which could never have been anticipated: and the fact should serve as a hint to those geologists who are fond of appealing to alluvial phenomena as proofs of the superior violence of aqueous causes in former ages.

The first account sent to Naples of the two great slides or landslips above alluded to, which caused a great lake near Terranuova, was couched in these words:—'Two mountains on the opposite sides of a valley walked from their original position until they met in the middle of the plain, and there joining together, they intercepted the course of a river, &c.' The expressions here used resemble singularly those applied to phenomena, probably very analogous, which are said to have occurred at Fez, during the great Lisbon earthquake, as also in Jamaica and Java at other periods.

Not far from Soriano, which was levelled to the ground by tne great shock of February the 5th, a small valley, containing a beautiful olive-grove, called Fra Ramondo, underwent a most extraordinary revolution. Innumerable fissures first traversed the river-plain in all directions, and absorbed the water until the argillaceous substratum became soaked, and a great part of it was reduced to a state of fluid paste. Strange alterations in the outline of the ground were the consequence, as the

soil to a great depth was easily moulded into any form. In addition to this change, the ruins of the neighbouring hills were precipitated into the hollow; and while many olives were

No. 26.

Changes of the surface at Fra Ramondo, near Soriano, in Calabria.

1. Portion of a hill covered with olives thrown down.
2. New bed of the river Caridi. 3. Town of Soriano.

uprooted, others remained growing on the fallen masses, and inclined at various angles (see cut No. 26). The small river Caridi was entirely concealed for many days; and when at length it reappeared, it had shaped for itself an entirely new channel.

Buildings transported entire to great distances.—Near Seminara, an extensive olive-ground and orchard were hurled to a distance of two hundred feet, into a valley sixty feet in depth. At the same time a deep chasm was riven in another part of the high plateau from which the orchard had been detached, and the river immediately entered the fissure, leaving its former bed completely dry. A small inhabited house, standing on the mass of earth carried down into the valley, went along with it entire, and without injury to the inhabitants. The olive-trees, also, continued to grow on the land which had slid into the valley, and bore the same year an abundant crop of fruit.

Two tracts of land on which a great part of the town of Polistena stood, consisting of some hundreds of houses, were detached into a contiguous ravine, and nearly across it about half a mile from their original site; and what is most extraordinary, several of the inhabitants were dug out from the ruins alive and unhurt.

Two tenements, near Mileto, called the Macini and Vaticano, about a mile long, and half a mile broad, were carried for a mile down a valley. A thatched cottage, together with large olive and mulberry trees, most of which remained erect, were carried uninjured to this extraordinary distance. According to Hamilton, the surface removed had been long undermined by rivulets, which were afterwards in full view on the bare spot deserted by the tenements. The earthquake seems to have opened a passage in the adjoining argillaceous hills, by which water charged with loose soil had suddenly taken its course into the subterranean channels of the rivulets immediately under the tenements, so that the entire piece of ground was floated off. Another example of subsidence, where the edifices were not destroyed, is mentioned by Grimaldi, as having taken place in the city of Catanzaro, the capital of the province of that name. The houses in the quarter called San Giuseppe subsided with the ground to various depths from two to four feet, but the buildings remained uninjured.

It would be tedious, and our space would not permit us, to follow the different authors through their local details of landslips produced in numerous minor valleys; but they are highly interesting, as showing to how great an extent the power of rivers to widen valleys, and to carry away large portions of soil towards the sea, is increased where earthquakes are of periodical occurrence. Among other territories, that of Cinquefrondi was greatly convulsed, various portions of soil being raised or sunk, and innumerable fissures traversing the country in all directions (see cut No. 27). Along the flanks of a small valley in this district there appears to have been an almost uninterrupted line of landslips.

No. 27.

Landslips near Cinquefrondi, caused by the earthquake of 1783.

Number of new-formed lakes.—Vivenzio states, that near Sitizzano a valley was very nearly filled up to a level with the high grounds on each side, by the enormous masses detached from the boundary hills, and cast down into the course of two streams. By this barrier a lake was formed of great depth, about two miles long and a mile broad. The same author mentions that, upon the whole, there were fifty lakes occasioned during the convulsions, and he assigns localities to all of these. The government surveyors enumerated two hundred and fifteen lakes, but they included in this number many small and insignificant ponds.

Currents of mud.—Near S. Lucido, among other places, the soil is described as having been 'dissolved,' so that large torrents of mud inundated all the low grounds, like lava. Just emerging from this mud, the tops only of trees and of the ruins of farm-houses were seen. Two miles from Laureana, the swampy soil in two ravines became filled with calcareous matter, which oozed out from the ground immediately before the first great shock. This mud, rapidly accumulating, began, ere long, to roll onward, like a flood of lava, into the valley, where the two streams uniting, moved forward with increased impetus from east to west. It now presented a breadth of

three hundred palms by twenty in depth, and before it ceased to move, covered a surface equal in length to an Italian mile. In its progress it overwhelmed a flock of thirty goats, and tore up by the roots many olive and mulberry-trees, which floated like ships upon its surface. When this calcareous lava had ceased to move, it gradually became dry and hard, during which process the mass was lowered ten palms. It contained fragments of earth of a ferruginous colour, and emitting a sulphureous smell.

Cones of sand thrown up.—Many of the appearances exhibited in the alluvial plains indicate clearly the alternate rising and sinking of the ground. The first effect of the more violent shocks was usually to dry up the rivers, but they immediately afterwards overflowed their banks. Along the alluvial plains, and in marshy places, an immense number of cones of sand were thrown up. These appearances Hamilton explains, by supposing that the first movement raised the fissured plain from below upwards, so that the rivers and stagnant waters

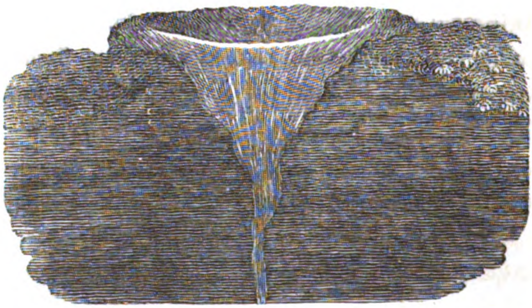
No. 28.

Circular hollows in the plain of Rosarno, formed by the earthquake of 1783.

in bogs sank down, or at least were not upraised with the soil. But when the ground returned with violence to its

former position, the water was thrown up in jets through fissures *.

Formation of circular hollows.—In the report of the Academy, we find that some plains were covered with circular hollows, for the most part about the size of carriage-wheels, but often somewhat larger or smaller. When filled with water to within a foot or two of the surface, they appeared like wells; but, in general, they were filled with dry sand, sometimes with a concave surface, and at other times convex. (See wood-cut No. 28). On digging down, they found them to be funnel-shaped, and the moist loose sand in the centre marked the tube up which the water spouted. The annexed cut represents a section of one of these inverted cones when the water had disappeared, and nothing but dry micaceous sand remained.



No. 29.

Section of one of the circular hollows formed in the plain of Rosarno.

Fall of the sea cliffs.—Along the sea-coast of the straits of Messina, near the celebrated rock of Scilla, the fall of huge masses detached from the bold and lofty cliffs overwhelmed many villas and gardens. At Gian Greco a continuous line of cliff, for a mile in length, was thrown down. Great agitation was frequently observed in the bed of the sea during the shocks, and, on those parts of the coast where the movement was most violent, all kinds of fish were taken in greater abundance, and with much greater facility. Some rare species, as that called Cicirelli, which usually lie buried in the sand,

* Phil. Trans. vol. lxxiii. p. 180.

were taken on the surface of the waters in great quantity. The sea is said to have boiled up near Messina, and to have been agitated as if by a copious discharge of vapours from its bottom.

Shore near Scilla inundated.—The Prince of Scilla had persuaded a great part of his vassals to betake themselves to their fishing-boats for safety, and he himself had gone on board. On the night of the 5th of February, when some of the people were sleeping in the boats, and others on a level plain slightly elevated above the sea, the earth rocked, and suddenly a great mass was torn from the contiguous Mount Jaci, and thrown down with a dreadful crash upon the plain. Immediately afterwards, the sea rising thirty palms above the level of this low tract, rolled foaming over it, and swept away the multitude. It then retreated, but soon rushed back again with greater violence, bringing with it some of the people and animals it had carried away. At the same time every boat was sunk or dashed against the beach, and some of them were swept far inland. The aged Prince, with one thousand four hundred and thirty of his people, was destroyed.

Number of persons who perished during the earthquake.—The number of persons who perished during the earthquake in the two Calabrias and Sicily is estimated by Hamilton at about forty thousand, and about twenty thousand more died by epidemics which were caused by insufficient nourishment, exposure to the atmosphere, and malaria, arising from the new stagnant lakes and pools. By far the greater number were buried under the ruins of their houses; while some were burnt to death in the conflagrations which almost invariably followed the shocks, and consumed immense magazines of oil and other provisions. A small number were engulphed in chasms and fissures, and their skeletons are perhaps buried in the earth to this day, at the depth of several hundred feet, for such was the profundity of some of the openings which did not close in again.

State of Stromboli and Etna during the shocks.—The inha-

bitants of Pizzo remarked that, on the 5th of February, 1783, when the first great shock afflicted Calabria, the volcano of Stromboli, which is in full view of that town, and at the distance of about fifty miles, smoked less, and threw up a less quantity of inflamed matter, than it had done for some years previously. On the other hand, the great crater of Etna is said to have given out a considerable quantity of vapour towards the beginning, and Stromboli towards the close of the commotions. But as no eruption happened from either of these great vents during the whole earthquake, the sources of the Calabrian convulsions, and of the volcanic fires of Etna and Stromboli, appear to be very independent of each other; unless, indeed, they have the same mutual relation as Vesuvius and the volcanos of the Phlegræan Fields and Ischia, a violent disturbance in one district serving as a safety-valve to the other, and both never being in full activity at once.

Excavation of Valleys.—It is impossible for the geologist to consider attentively the effect of this single earthquake of 1783, and to look forward to the alterations in the physical condition of the country to which a continued series of such movements will hereafter give rise, without perceiving that the formation of valleys by running water can never be understood, if we consider the question independently of the agency of earthquakes. Rivers do not begin to act, as some seem to imagine, when a country is already elevated far above the level of the sea, but while it is *rising* or *sinking* by successive movements. Whether Calabria is now undergoing any considerable change of relative level, in regard to the sea, or is, upon the whole, nearly stationary, is a question which our observations, confined almost entirely to the last half-century, cannot possibly enable us to determine. But we know that strata, containing species of shells identical with those now living in the contiguous parts of the Mediterranean, have been raised in this country, as they have in Sicily, to the height of several thousand feet.

Now those geologists who merely grant that the present

course of Nature, in the inanimate world, has been unchanged since the existing species of animals were in being, will not feel surprise that the Calabrian streams and rivers have cut out of such comparatively modern strata a great system of valleys varying in depth from fifty to six hundred feet, and often several miles wide, when they consider how numerous must have been the earthquakes which lifted those recent marine strata to so prodigious a height. Some speculators, indeed, who disregard the analogy of existing Nature, and who are as prodigal of violence as they are thrifty of time, may suppose that Calabria 'rose like an exhalation' from the deep, after the manner of Milton's Pandemonium. But such an hypothesis would deprive them of that peculiar removing force required to form a regular system of deep and wide valleys, for *time* is essential to the operation. Landslips must be cleared away in the intervals between subterranean movements, otherwise fallen masses will serve as buttresses to the precipitous cliffs bordering a valley, so that the succeeding earthquake will be unable to exert its full power. Barriers must be worn through and swept away, and steep or overhanging cliffs again left without support, before another shock can take effect in the same manner.

If a single convulsion be too violent, and agitate at once an entire hydrographical basin, or if the shocks follow each other too rapidly, the previously-existing valleys will be annihilated, instead of being modified and enlarged. Every stream will be compelled to begin its operations anew, and to open for itself a passage through strata before undisturbed, instead of continuing to deepen and widen channels already in great part excavated. On the other hand, if, consistently with all that is known from observation of the laws which regulate subterranean movements, we consider their action to have been intermittent—if sufficient periods have always intervened between the severer shocks to allow the drainage of the country to be nearly restored to its original state, then are both the kind and degree of force supplied which may enable running water to

hollow out a valley of any depth and size consistent with the degree of elevation above the sea which the district in question may happen at any time to have attained during a succession of physical revolutions.

Notwithstanding the great derangement caused by violent earthquakes, there is an evident tendency in running water to remain constant to the same connected series of valleys. The softening of the soil is invariably greatest in the channels of rivers and in alluvial plains. The water is absorbed in an infinite number of rents, and when the ground is swelled with water, it is reduced almost to a state of mud by the vehement agitation of the ground in every direction, and often for several years consecutively. The erosive and transporting action of running water is therefore facilitated in the tracts already excavated.

When we read of the drying up and desertion of the channels of rivers, the accounts most frequently refer to their deflection into some other part of the same alluvial plain, perhaps several miles distant. Under certain circumstances a change of level may undoubtedly force the water to flow over into some distinct hydrographical basin; but even then it will fall immediately into valleys already formed. Provided, therefore, we suppose the elevation and subsidence of mountain-chains to be a gradual process, there is no difficulty in explaining how the rivers draining our continents have converted ravines into valleys, and enlarged and deepened valleys to an enormous extent. On the contrary, the signs of slow and gradual action so manifest in the sinuosities and other characters of valleys are admirably reconcileable with the great width and depth of the excavations, if we are content not only to suppose a great succession of ordinary earthquakes, but also the usual intervals of time between the shocks.

We may observe that earthquakes alone could never give rise to a regular system of valleys ramifying from a main trunk like the small vessels from the great arteries of the human body. On the contrary, they would in the course of time

destroy every system of valleys on the globe, were it not for the agency of aqueous causes. We learn from history that, ever since the first Greek colonists, the Bruttii, settled in Calabria, that region has been subject to devastation by earthquakes, and, for the last century and a half, ten years have seldom elapsed without a shock; but the severer convulsions have not only been separated by intervals of twenty, fifty, or one hundred years, but have not affected precisely the same points when they recurred. Thus the earthquake of 1783, although confined within the same geographical limits as that of 1638, and not very inferior in violence, visited, according to Grimaldi, very different localities. The points where the local intensity of the force is developed, being thus perpetually varied, more time is allowed for the removal of separate mountain masses thrown into river channels by each shock.

When chasms and deep hollows open at the bottom of valleys, they must often be filled with those 'mud lavas' before described; and these must be extremely analogous to the enormous ancient deposits of mud which are seen in many countries, as in the basin of the Tay, Isla, and North Esk rivers, for example, in Scotland—alluvions hundreds of feet thick, which are neither stratified nor laminated like the sediment which subsides from water. Whenever a landslip blocks up a river, these currents of mud will be arrested, and accumulate to an enormous depth.

The transportation for several miles at a time of masses as large as great edifices, by the momentum of these floods of mud combined with the motion of the earthquake, and the enveloping of land animals, together with many other facts mentioned in the Calabrian account, cannot but excite in the mind of every geologist a strong desire to become more acquainted with the changes now in progress in those vast regions of the globe which are habitually devastated by earthquakes. To our extreme ignorance of this important class of phenomena we may probably refer the obscurity of many of the appearances of superficial alluvions throughout the

greater part of Europe, as well as the diversity of opinion relating to them, and the extravagant theories which have passed current.

The portion of the Calabrian valleys formed within the last three thousand years must, undoubtedly, be inconsiderable in amount, compared to that previously formed, just as the lavas which have flowed from Etna since the historical era constitute but a small proportion of the whole cone. But as a continued series of such eruptions as man has witnessed would reproduce another cone like Etna, so a sufficient number of earthquakes like that of 1783 would enable torrents and rivers to re-excavate all the Calabrian valleys if they were now to be entirely obliterated. It must be evident that more change is effected in two centuries in the width and depth of the valleys of that region, than in many thousand years in a country as undisturbed by earthquakes as Great Britain. For the same reason, therefore, that he who desires to comprehend the volcanic phenomena of Central France will repair to Vesuvius, Etna, or Hecla, so they who aspire to explain the mode in which valleys are formed must visit countries where earthquakes are of frequent occurrence. For we may be assured, that the power which uplifted our more ancient tertiary strata of marine origin to more than a thousand feet above the level of the sea, co-operated at some former epoch with the force of rivers in the removal of large portions of rock and soil, just as the elevatory power which has upraised new strata to the height of several thousand feet in the south of Italy has caused those formations to be already intersected by deep valleys and ravines.

He who studies the hydrographical basin of the Thames, and compares its present state with its condition when it was a Roman province, may have good reason to declare that if that river and its tributaries had since their origin been always as inactive, and as impotent as they are now, they could never, not even in millions of years, have excavated the valleys through which they flow: but, if he concludes from these

premises, that the valleys in this basin were not formed by ordinary causes, he reasons like one, who having found a solfatara which for many centuries has thrown out nothing more than vapour and a few handfuls of sand and scoriæ, infers that a lofty cone, composed of successive streams of lava and ejections, can no longer be produced by volcanic agency.

CHAPTER XXV.

Earthquakes of the eighteenth century, *continued*—Guatimala, 1777—Java, 1772—Truncation of a lofty cone—Caucasus, 1772—Java, 1771—St. Domingo, 1770—Colombia, 1766—Chili, 1760—Azores, 1757—Lisbon, 1755—Sinking down of the quay to the depth of six hundred feet—Shocks felt throughout Europe, Northern Africa, and the West Indies—Great wave—Shocks felt at sea—St. Domingo, 1751—Conception Bay, 1750—Permanent elevation of the bed of the sea to the height of twenty-four feet—Peru, 1746—Kamtschatka, 1737—Martinique, 1727—Iceland, 1725—Teneriffe, 1706—Java, 1699—Landslips obstruct the Batavian and Tangaran rivers—Quito, 1698—Sicily, 1693—Subsidence of land—Moluccas, 1693—Jamaica, 1692—Large tracts engulphed—Portion of Port Royal sunk from twenty to fifty feet under water—The Blue Mountains shattered—Reflections on the amount of change in the last one hundred and forty years—Proofs of elevation and subsidence of land on the coast of the Bay of Baiæ—Evidence of the same afforded by the present state of the Temple of Serapis.

EARTHQUAKES OF THE EIGHTEENTH CENTURY, *continued*.

In the preceding chapters we have considered a small part of those earthquakes only which have occurred during the last fifty years, of which accurate and authentic descriptions happen to have been recorded. We shall next proceed to examine some of earlier date, respecting which information of geological interest has been obtained.

Guatimala, June, 1777.—The town of Guatimala, in Mexico, was founded in 1742 on the side of a volcano, in a valley about three miles wide opening to the South sea; nine years afterwards it was destroyed by an earthquake, and again, in 1777, during an eruption of the volcano. The ground on which the town stood gaped open in deep fissures, until at length, after five days, an abyss opened, and the city, with all its riches and eight thousand families, was swallowed up. All vestiges of its former existence were entirely obliterated, and the spot is now indicated by a frightful desert, four leagues distant from the present town *.

* Malte-Brun, vol. v. part 2, p. 347.

Java, 1772—*Truncation of a lofty cone.*—In the year 1772, Papandayang, formerly one of the loftiest volcanos in the island of Java, was in eruption. Before all the inhabitants on the declivities of the mountain could save themselves by flight, the ground began to give way, and a great part of the volcano fell in and disappeared. It is estimated that an extent of ground of the mountain itself and its immediate environs fifteen miles long and full six broad, was by this commotion swallowed up in the bowels of the earth. Forty villages were destroyed, some being engulphed and some covered by the substances thrown out on this occasion, and 2957 of the inhabitants perished. A proportionate number of cattle were also killed, and most of the plantations of cotton, indigo, and coffee in the adjacent districts were buried under the volcanic matter. This catastrophe appears to have resembled, although on a grander scale, that of the ancient Vesuvius in the year 79. The cone was reduced in height from nine thousand to about five thousand feet, and, as vapours still escape from the crater on its summit, a new cone may one day rise out of the ruins of the ancient mountain, as the modern Vesuvius has risen from the remains of Somma *.

Caucasus, 1772.—About the year 1772, an earthquake convulsed the ground in the province of Beshtau, in the Caucasus, so that part of the hill Metshuka sunk into an abyss †.

Java, 1771.—By an earthquake in the year 1771, several tracts of ground were upraised in Java, and a new bank made its appearance opposite the mouth of the river of Batavia ‡.

St. Domingo, 1770.—During a tremendous earthquake which destroyed a great part of St. Domingo, innumerable fissures were caused throughout the island, from which mephitic vapours emanated and produced an epidemic. *Hot springs*

* Dr. Horsfield, Batav. Trans., vol. viii., p. 26. Dr. H. informs me that he has seen this truncated mountain, and though he did not ascend it, he has conversed with those who have examined it. Raffles's account (History of Java, vol. i.) is derived from Horsfield.

† Pallas's Travels in Southern Russia.

‡ Raffles's History of Java, vol. ii., p. 232.

burst forth in many places where there had been no water before, but after a time they ceased to flow *.

Colombia, 1766.—On the 21st of October, 1766, the ground was agitated at once at Cumana, at Caraccas, at Maracaybo, and on the banks of the rivers Casanare, the Meta, the Orinoco, and the Ventuario. These districts were much fissured, and great fallings in of the earth took place in the mountain Paurari: Trinidad was violently shaken. A small island in the Orinoco, near the rock Aravacoto, sunk down and disappeared †. At the same time the ground was raised in the sea near Cariaco, where the Point Del Gardo was enlarged. A rock also rose up in the river Guarapica, near the village of Maturin ‡. The shocks continued in Colombia hourly for fourteen months.

Chili, 1760.—In 1760, the volcano Peteroa, in Chili, was in eruption, and formed a new crater. A fissure, several miles in length, opened in a neighbouring hill, and a great landslip obstructed the river Lontue for ten days, giving rise to a considerable lake.

Azores, 1757.—In the year 1757, the island of St. George was struck by an earthquake, and eighteen small islets rose at the distance of about two hundred yards from the shore. These may possibly have been produced by a submarine eruption.

Lisbon, 1755.—In no part of the volcanic region of southern Europe has so tremendous an earthquake occurred in modern times as that which began on the 1st of November, 1755, at Lisbon. A sound of thunder was heard under ground, and immediately afterwards a violent shock threw down the greater part of that city. In the course of about six minutes, sixty thousand persons perished. The sea first retired and laid the bar dry; it then rolled in, rising fifty feet or more above its

* Essai sur l'Hist. Nat. de l'isle de St. Domingue, Paris, 1776.

† Humboldt's Personal Narrative, vol. iv., p. 45, and Saggio di Storia Americana, vol. ii. p. 6.

‡ Humboldt, Voy. Relat. Hist., part i., p. 307, and part ii., p. 23.

ordinary level. The mountains of Arrabida, Estrella, Julio, Marvan, and Cintra, being some of the largest in Portugal, were impetuously shaken, as it were, from their very foundations; and most of them opened at their summits, which were split and rent in a wonderful manner, huge masses of them being thrown down into the subjacent valleys *. Flames are related to have issued from these mountains, which are supposed to have been electric; they are also said to have smoked; but vast clouds of dust seem to have given rise to this appearance.

Subsidence of the Quay.—The most extraordinary circumstance which occurred at Lisbon during the catastrophe was the subsidence of a new quay, built entirely of marble at an immense expense. A great concourse of people had collected there for safety, as a spot where they might be beyond the reach of falling ruins; but, suddenly, the quay sank down with all the people on it, and not one of the dead bodies ever floated to the surface. A great number of boats and small vessels anchored near it, all full of people, were swallowed up, as in a whirlpool †. No fragments of these wrecks ever rose again to the surface, and the water in the place where the quay had stood is stated, in many accounts, to be unfathomable; but, Whitehurst ‡ says, he ascertained it to be one hundred fathoms.

In this case, we must either suppose that a certain tract sank down into a subterranean hollow which would cause a 'fault' in the strata to the depth of six hundred feet, or we may infer, as some have done, from the entire disappearance of the substances engulphed, that a chasm opened and closed again. Yet, in adopting this latter hypothesis, we must suppose that the

* Hist. and Philos. of Earthquakes, p. 317.

† Rev. C. Davy's Letters, vol. ii., Letter ii., p. 12, who was at Lisbon at the time, and ascertained that the boats and vessels said to have been swallowed were missing.

‡ On the Formation of the Earth, p. 55.

upper part of the chasm, to the depth of one hundred fathoms, remained open.

Area over which this earthquake was felt.—The great area over which this Lisbon earthquake extended is very remarkable. The movement was most violent in Spain, Portugal, and the north of Africa; but nearly the whole of Europe, and even the West Indies, felt the shock on the same day. A sea-port, called St. Eubals, about twenty miles south of Lisbon, was engulphed. At Algiers and Fez, in Africa, the agitation of the earth was equally violent, and at the distance of eight leagues from Morocco, a village, with the inhabitants to the number of about eight or ten thousand persons, together with all their cattle, were swallowed up. Soon after the earth closed again over them.

Great wave caused by it.—A great wave swept over the coast of Spain, and is said to have been sixty feet high at Cadiz. At Tangier, in Africa, it rose and fell eighteen times on the coast. At Funchal, in Madeira, it rose full fifteen feet perpendicular above high-water mark, although the tide which ebbs and flows there seven feet was then at half ebb. Besides entering that city, and committing great havoc, it overflowed other sea-ports in the island. At Kinsale, in Ireland, a body of water rushed into the harbour, whirled round several vessels, and poured into the market-place.

Shocks felt at sea.—The shock was felt at sea, on the deck of a ship to the west of Lisbon, and produced very much the same sensation as on dry land. Off St. Lucar, the captain of the Nancy frigate felt his ship so violently shaken that he thought he had struck the ground; but, on heaving the lead, found he was in a great depth of water. Captain Clark from Denia, in north latitude 36° 24′, between nine and ten in the morning, had his ship shaken and strained as if she had struck upon a rock, so that the seams of the deck opened, and the compass was overturned in the binnacle. Another ship forty leagues west of St. Vincent experienced so violent a concussion,

that the men were thrown a foot and a half perpendicularly up from the deck. In Antigua and Barbadoes, as also in Norway, Sweden, Germany, Holland, Corsica, Switzerland, and Italy, tremors and slight oscillations of the ground were felt.

Rate at which the movement travelled.—The agitation of lakes, rivers, and springs, in Great Britain was remarkable. At Loch Lomond, in Scotland, for example, the water, without the least apparent cause, rose against its banks, and then subsided below its usual level. The greatest perpendicular height of this swell was two feet four inches. It is said that the movement of this earthquake was undulatory, and that it travelled at the rate of twenty miles a minute, its velocity being calculated by the intervals between the time when the first shock was felt at Lisbon, and its time of occurrence at other distant places *.

St. Domingo, 1751.—On the 15th of September, 1751, a shock began to be experienced in several of the West India islands, and on the 21st of November, a violent one destroyed the capital of St. Domingo, Port au Prince. Part of the coast, twenty leagues in length, sank down and has ever since formed a bay of the sea †.

Conception, 1750.—On the 24th of May, 1750, the ancient town of Conception, otherwise called Penco, in Chili, was totally destroyed by an earthquake, and the sea rolled over it. The ancient port was rendered entirely useless, and the inhabitants built another town ten miles from the sea-coast, in order to be beyond the reach of similar inundations.

Proofs of elevation of twenty-four feet.—During a late survey of Conception Bay, Captains Beechey and Belcher discovered that the ancient harbour, which formerly admitted all large merchant vessels which went round the Cape, is now occupied by a reef of sandstone, certain points of which project above the sea at low water, the greater part being very

* Michell on the Cause and Phenomena of Earthquakes, Phil. Trans., vol. li. p. 566. 1760.

† Hist. de l'Acad. des Sciences. 1752. Paris.

shallow. A tract of a mile and a half in length, where, according to the report of the inhabitants, the water was formerly four or five fathoms deep, is now a shoal. The correctness of this statement of the original depth may be concluded from the circumstance, that the large trading vessels which formerly frequented the port could not have anchored in less than four fathoms water. Our hydrographers found the reef to consist of hard sandstone, so that it cannot be supposed to have been formed by recent deposits of the river Biobio, an arm of which carries down loose micaceous sand into the same side of the bay. Besides, it is a well-known fact, that ever since the shock of 1750, no vessels have been able to approach within a mile and a half of the ancient port of Penco. That shock, therefore, uplifted the bed of the sea to the height of twenty-four feet at the least, and most probably the adjoining coast shared in the elevation, for an enormous bed of shells of the same species as those now living in the bay, are seen raised above high-water mark along the beach, filled with micaceous sand like that which the Biobio now conveys to the bay. These shells, as well as others which cover the adjoining hills of mica-schist to the height of from one thousand to one thousand five hundred feet, have lately been examined by experienced conchologists in London, and identified with those taken at the same time in a living state from the bay and its neighbourhood *.

Ulloa, therefore, was perfectly correct in his statement, that at various heights above the sea between Talcaguana and Conception, 'mines were found of various sorts of shells used for lime of the very same kinds as those found in the adjoining sea.' Among them, he mentions the great mussel called Choros, and two others which he describes. Some of these, he says, are entire, and others broken; they occur at the bottom of the sea, in four, six, ten, or twelve fathom water, where they adhere to a sea-plant called Cochayuyo. They are taken in dredges, and have no resemblance to those found on the shore

* Captain Belcher has shown me these shells, and the collection has been examined by Mr. Broderip.

or in shallow water, yet beds of them occur at various heights on the hills. 'I was the more pleased with the sight,' he adds, 'as it appeared to me a convincing proof of the universality of the deluge, although I am not ignorant that some have attributed their position to other causes; but an unanswerable confutation of their subterfuge is, that the various sorts of shells which compose these strata, both in the plains and mountains, are the very same with those found in the bay *.' Perhaps the diluvian theory of this distinguished navigator, the companion of Condamine, may account for his never having recorded even reports of changes in the relative level of land and sea on the shores of South America. He could not, however, have given us a relation of the rise of the reef above alluded to, for the destruction of Penco happened a few years after the publication of his Voyages.

If we duly consider these facts so recently brought to light, as well as the elevation before mentioned of the coast at Valparaiso in 1822, we shall be less sceptical than Raspe, in regard to an event for which Hooke had cited Purchas's Travels. In that passage it was stated, 'that a certain sea-coast in a pro vince of South America called Chili, was, during a violent earthquake, propelled upwards with such force and velocity, that some ships on the sea were grounded in it, and the sea receded to a distance.' Raspe, being himself of opinion that all the continents had been upraised gradually by earthquakes from the sea, admitted that the circumstance was not impossible, but he complains that Purchas had interpolated the account of the earthquake (which happened probably at the close of the seventeenth century) into Da Costa's History of the West Indies †.

Peru, 1746.—Peru was visited on the 28th of October, 1746, by an earthquake, which is declared to have been more tremendous and extensive than even that of Lisbon in 1755. In the first twenty-four hours, two hundred shocks were experi-

* Ulloa's Voyage to South America, vol. ii. book viii. ch. vi.

† De Novis Insulis, p. 120. 1753.

enced. The ocean twice retired and returned impetuously upon the land: Lima was destroyed, and part of the coast near Callao was converted into a bay; four other harbours, among which were Cavalla and Guanape, shared the same fate. There were twenty-three ships and vessels great and small in the harbour of Callao, of which nineteen were sunk, and the other four, among which was a frigate called St. Fermin, were carried by the force of the waves to a great distance up the country. The number of the inhabitants in this city amounted to four thousand. Two hundred only escaped, twenty-two of whom were saved on a small fragment of the fort of Vera Cruz, which remained as the only memorial of the site of the town after this dreadful inundation.

A volcano in Lucanas burst forth the same night, and such quantities of water descended from the cone, that the whole country was overflowed; and in the mountain near Patao, called Conversiones de Caxamarquilla, three other volcanos burst out, and frightful torrents of water swept down their sides *.

In regard to changes of level, there is a story at Lima, that part of the promontory south of Callao sank down, and that a navigable channel between the isle of San Lorenzo and the main land was then formed. According to other reports, the submerged arches of a church and the position of several buildings, indicate a subsidence on the ancient site of Callao. It is to be hoped that the evidence of these changes will soon be inquired into.

Kamtschatka, 1737.—The eastern side of the peninsula of Kamtschatka, at Awatchka bay, was shaken by an earthquake on October the 6th, 1737. The sea was violently agitated, and overflowed the land to an immense height, and then withdrew so far as to lay bare its bottom between the first and second of the Kurile Isles. The shape of the ground was greatly changed. Several plains were uplifted and formed

* Ulloa's Voyage, vol. ii. book vii. chap. vii.

hills, and on the other hand many subsidences occasioned inland lakes and new bays on the coast*.

Martinique, 1727.—In the year 1727, a hill sunk down in Martinique during an earthquake †.

Iceland, 1725.—In Iceland during the eruption of the volcano Leirhnukur, in 1725-6, a tract of high land sunk down, and formed a lake, and half a mile from the same place a hill rose in a lake and converted it into dry land ‡.

Teneriffe, 1706.—May 5th, 1706, a lateral eruption of Teneriffe took place south of the harbour of Garachico, which was overwhelmed with lava. Many springs disappeared, and there were such changes of level as to alter the whole face of the country, hills having risen up where there were plains before §.

Java, 1699.—On the 5th of January, 1699, a terrible earthquake visited Java, and no less than two hundred and eight considerable shocks were reckoned. Many houses in Batavia were overturned, and the flame and noise of a volcanic eruption were seen and heard in that city, which were afterwards found to proceed from Mount Salak ‖, a volcano six days' journey distant. Next morning the Batavian river, which has its rise from that mountain, became very high and muddy, and brought down abundance of bushes and trees, half burnt. The channel of the river being stopped up, the water overflowed the country round, the gardens about the town, and some of the streets, so that fishes lay dead in them. All the fish in the river, except the carps, were killed by the mud and turbid water. A great number of drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down by the current, and 'notwithstanding,' observes one of the

* Kracheninikon by Chappe d'Auteroche, p. 337.

† Geog. of America, Schlözer, Part II. p. 554.

‡ Dureau de la Malle, Géog. de la Mer Noire, p. 203.

§ Humboldt and Bonpland, Voy. Relat. Hist., Part I. p. 177.

‖ Mis-spelt Sales in Hooke's account.

writers, 'that a crocodile is amphibious, several of them were found dead among the rest *.'

It is stated, that seven hills bounding the river sank down, by which is merely meant, as by similar expressions in the description of the Calabrian earthquakes, seven great landslips. These hills, descending some from one side of the valley and some from the other, filled the channel, and the waters then finding their way under the mass, flowed out thick and muddy. The Tangaran river was also dammed up by nine hills, and in its channel were large quantities of drift trees. Seven of its tributaries also are said to have been 'covered up with earth.' A high tract of forest land, between the two great rivers before mentioned, is described as having been changed into an open country, destitute of trees, the surface being spread over with a fine red clay. This part of the account may, perhaps, merely refer to the sliding down of woody tracts into the valleys, as happened to so many extensive vineyards and olive-grounds in Calabria, in 1783. The close packing of large trees in the Batavian river is represented as very remarkable, and it attests in a striking manner the destruction of soil bordering the valleys which had been caused by floods and landslips †.

Quito, 1698.—In Quito, on the 19th of July, 1698, during an earthquake, a great part of the crater and summit of the volcano Carguairazo fell in, and a stream of water and mud issued from the broken sides of the hill ‡.

Sicily, 1693.—Shocks of earthquakes spread over all Sicily in 1693, and on the 11th of January the city of Catania and forty-nine other places were levelled to the ground, and about one hundred thousand people killed. The bottom of the sea, says Vicentino Bonajutus, sank down considerably both in ports, inclosed bays, and open parts of the coast, and water bubbled up along the shores. Numerous long fissures of various

* Hooke's Posthumous Works, p. 437, 1705.

† Phil. Trans., 1700.

‡ Humboldt, Atl. Pit., p. 106.

breadths were caused, which threw out sulphureous water, and one of them, in the plain of Catania (the delta of the Simeto), at the distance of four miles from the sea, sent forth water as salt as the sea. The stone buildings of a street in the city of Noto, for the length of half a mile, sank into the ground, and remained hanging on one side. In another street, an opening large enough to swallow a man and horse appeared*.

Moluccas, 1693.—The small isle of Sorea, which consists of one great volcano, was in eruption in the year 1693. Different parts of the cone fell one after the other into a deep crater, until almost half the space of the island was converted into a fiery lake. Most of the inhabitants fled to Banda, but great pieces of the mountain continued to fall down, so that the lake became wider, and finally the whole population was compelled to emigrate. It is stated, that in proportion as the lake of lava increased in size, the earthquakes were less vehement†.

Jamaica, 1692.—In the year 1692 the island of Jamaica was visited by a violent earthquake, the ground swelled and heaved like a rolling sea, and was traversed by numerous cracks, two or three hundred of which were often seen at a time opening and then closing rapidly again. Many people were swallowed up in these rents; some the earth caught by the middle and squeezed to death; the heads of others only appeared above ground, and some were first engulphed, and then cast up again with great quantities of water. Such was the devastation, that even at Port Royal, then the capital, where more houses are said to have been left standing than in the whole island beside, three-quarters of the buildings, together with the ground they stood on, sank down with their inhabitants entirely under water.

Subsidence in the harbour.—The large store-houses on the harbour side subsided, so as to be twenty-four, thirty-six, and forty-eight feet under water; yet many of them appear to have remained standing, for it is stated that, after the earthquake, the mast-heads of several ships wrecked in the harbour, toge-

* Phil. Trans., 1693-4. † Ibid. 1693.

ther with the chimney-tops of houses, were just seen projecting above the waves. A tract of land round the town, about a thousand acres in extent, sank down in less than one minute, during the first shock, and the sea immediately rolled in. The Swan frigate, which was repairing in the wharf, was driven over the tops of many buildings, and then thrown upon one of the roofs, through which it broke. The breadth of one of the streets is said to have been doubled by the earthquake.

According to Mr. De la Beche, the part of Port Royal described as having sunk, was built upon newly-formed land, consisting of sand in which piles had been driven, and the *settlement* of this loose sand, charged with the weight of heavy houses, may have given rise to the subsidences alluded to*. There can be no doubt that a waving motion of the earth, accompanied by an inroad of the sea, might affect loose sand, while solid rock might remain unmoved; but, after attentively considering the original documents, we are inclined to believe that there were various and unequal subsidences of the land at Port Royal, independently of any sliding and undermining of the sands.

At several thousand places in Jamaica, the earth is related to have opened. On the north of the island several plantations, with their inhabitants, were swallowed up, and a lake appeared in their place, covering above a thousand acres, which afterwards dried up, leaving nothing but sand and gravel, without the least sign that there had ever been a house or tree there. Several tenements at Yallowes were buried under landslips; and one plantation was removed half a mile from its place, the crops continuing to grow upon it uninjured. Between Spanish town and Sixteen-mile-walk the high and perpendicular cliffs bounding the river, fell in, stopped the passage of the river, and flooded the latter place for nine days, so that the people 'concluded it had been sunk as Port Royal was.' But the flood at length subsided, for the river had found some new passage at a great distance.

* Manual of Geol., p. 133, second edition.

Mountains shattered.—The Blue and other of the highest mountains are declared to have been strangely torn and rent. They appeared shattered and half-naked, no longer affording a fine green prospect, as before, but stripped of their woods and natural verdure. The rivers on these mountains first ceased to flow for about twenty-four hours, and then brought down into the sea at Port Royal and other places, several hundred thousand tons of timber which looked like floating islands on the ocean. The trees were in general barked, most of their branches having been torn off in the descent. It is particularly remarked in this, as in the narratives of so many earthquakes, that fish were taken in great numbers on the coast during the shocks. The correspondents of Sir Hans Sloane, who collected with care the accounts of eye-witnesses of the catastrophe, refer constantly to *subsidences*, and some supposed the whole of Jamaica to have sunk down*.

Reflections on the amount of change in the last one hundred and forty years.—We have now only enumerated the earthquakes of the last hundred and forty years, respecting which, facts illustrative of geological inquiries are on record. Even if our limits permitted, it would be a tedious and unprofitable task to examine all the obscure and ambiguous narratives of similar events of earlier epochs, although, if the localities were now examined by geologists well practised in the art of interpreting the monuments of physical changes, many events which have happened within the historical era might still be determined with precision. The reader must not imagine, that in our sketch of the occurrences in the short period above alluded to, we have given an account of all, or even the greater part of the mutations which the earth has undergone, by the agency of subterranean movements. Thus, for example, the earthquake of Aleppo, in the present century, and of Syria in the middle of the eighteenth, would doubtless have afforded numerous phenomena of great geological importance, had those catastrophes been described by scientific observers. The

* Phil. Trans., 1694.

shocks in Syria in 1759, were protracted for three months, throughout a space of ten thousand square leagues, an area compared to which that of the Calabrian earthquake, of 1783, was insignificant. Accon, Saphat, Balbeck, Damascus, Sidon, Tripoli, and many other places, were almost entirely levelled to the ground. Many thousands of the inhabitants perished in each, and in the valley of Balbeck alone twenty thousand men are said to have been victims to the convulsion. It would be as irrelevant to our present purpose to enter into a detailed account of such calamities, as to follow the track of an invading army, to enumerate the cities burnt or rased to the ground, and reckon the number of individuals who perished by famine or the sword.

Deficiency of historical records.—If such then be the amount of ascertained changes in the last one hundred and forty years, notwithstanding the extreme deficiency of our records during that brief period, how important must we presume the physical revolutions to have been in the course of thirty or forty centuries, during which, some countries habitually convulsed by earthquakes have been peopled by civilized nations! Towns engulphed during one earthquake may, by repeated shocks, have sunk to enormous depths beneath the surface, while their ruins remain as imperishable as the hardest rocks in which they are inclosed. Buildings and cities submerged for a time beneath seas or lakes, and covered with sedimentary deposits, must, in some places, have been re-elevated to considerable heights above the level of the ocean. The signs of these events have probably been rendered visible by subsequent mutations, as by the encroachments of the sea upon the coast, by deep excavations made by torrents and rivers, by the opening of new ravines and chasms, and other effects of natural agents, so active in districts agitated by subterranean movements.

If it be asked why, if such wonderful monuments exist, so few have hitherto been brought to light—we reply—because they have not been searched for. In order to rescue from

oblivion the memorials of former occurrences, we must know what we may reasonably expect to discover; and under what peculiar local circumstances. The inquirer, moreover, must be acquainted with the action and effects of physical causes, in order to recognize, explain, and describe correctly the phenomena when they present themselves.

The best known of the great volcanic regions of which we sketched the boundaries in the eighteenth chapter, is that which includes Southern Europe, Northern Africa, and Central Asia, yet nearly the whole even of this region must be laid down in a geological map as 'Terra Incognita.' Even Calabria may be regarded as unexplored, as also Spain, Portugal, the Barbary states, the Ionian Isles, the Morea, Asia Minor, Cyprus, Syria, and the countries between the Caspian and Black Seas. We are, in truth, beginning to obtain some insight into one small spot of that great zone of volcanic disturbance, the district around Naples, a tract by no means remarkable for the violence of the earthquakes which have convulsed it.

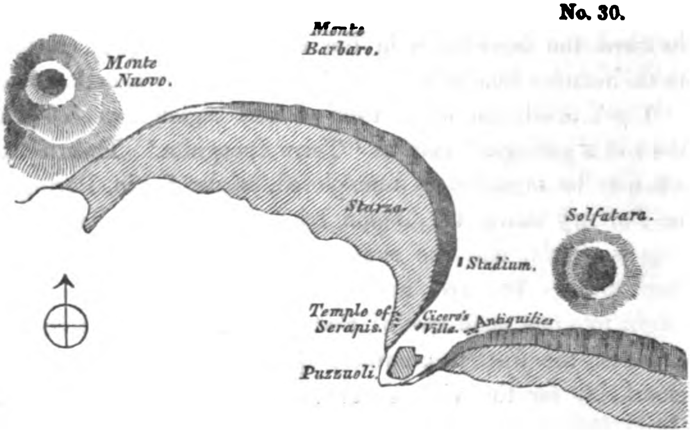
If, in this part of Campania, we are enabled to establish, that considerable changes in the relative level of land and sea have taken place since the Christian era, it is all that we could have expected, and it is to recent antiquarian and geological research, not to history, that we are principally indebted for the information. We shall proceed to lay before the reader some of the results of modern investigations in the Bay of Baiæ and the adjoining coast.

PROOFS OF ELEVATION AND SUBSIDENCE IN THE BAY OF BAIÆ.

Temple of Jupiter Serapis.—This celebrated monument of antiquity affords, in itself alone, unequivocal evidence, that the relative level of land and sea has changed twice at Puzzuoli since the Christian era; and each movement both of elevation and subsidence has exceeded twenty feet. Before examining these proofs, we may observe, that a geological examination of

the coast of the Bay of Baiæ, both on the north and south of Puzzuoli, establishes in the most satisfactory manner an elevation at no remote period, of more than twenty feet, and at one point of more than thirty feet, and the evidence of this change would have been complete even if the temple had to this day remained undiscovered.

No. 30.



Ground plan of the coast of the Bay of Baiæ in the environs of Puzzuoli.

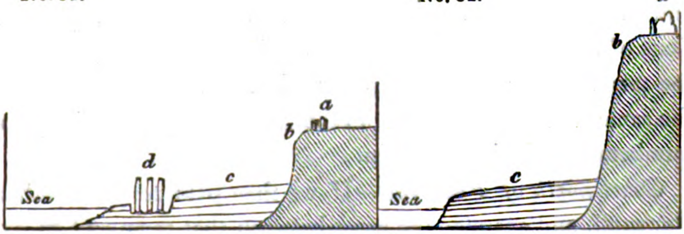
Coast south of Puzzuoli.—If we coast along the shore from Naples to Puzzuoli we find, on approaching the latter place, that the lofty and precipitous cliffs of indurated tuff, resembling that of which Naples is built, retire slightly from the sea, and that a low level tract of fertile land, of a very different aspect, intervenes between the present sea-beach, and what was evidently the ancient line of coast.

The inland cliff may be seen opposite the small island of Nisida, about two miles and a half south-east of Puzzuoli, where at the height of thirty-two feet above the level of the sea, Mr. Babbage observed an ancient mark, such as might have been worn by the waves, and, upon further examination, discovered that, along that line, the face of the perpendicular rock, consisting of very hard tuff, was covered with barnacles (*Balanus sulcatus*, Lamk.), and drilled by boring testacea. Some of the hollows of the Lithodomi contained the shells,

while others were filled with the valves of a species of Arca *. Nearer to Puzzuoli the inland cliff is eighty feet high, and as perpendicular as if it was still undermined by the waves. At its base, a new deposit, constituting the fertile tract above alluded to, attains a height of about twenty feet above the sea, and since it is composed of regular sedimentary deposits, containing marine shells, its position proves that, subsequently to its formation, there has been a change of more than twenty feet in the relative level of land and sea.

The sea encroaches on these new incoherent strata, and as the soil is valuable, a wall has been built for its protection; but when I visited the spot in 1828, the waves had swept away part of this rampart, and exposed to view a regular series of

No. 31. No. 32.



Sections exhibiting the relation of the recent marine deposits to the more ancient in the Bay of Baiæ.

a. Remains of Cicero's villa, N. side of Puzzuoli †.
b. Ancient cliff now inland.
c. Terrace composed of recent submarine deposit.
d. Temple of Serapis.

a. Antiquities on hill S.E. of Puzzuoli.
b. Ancient cliff now inland.
c. Terrace composed of recent submarine deposit.

strata of tuff, more or less argillaceous, alternating with beds of pumice and lapilli, and containing great abundance of

* Mr. Babbage examined this spot in company with Mr. Head, in June 1828, and has shown me numerous specimens of the shells collected here, and in the Temple of Serapis. The above particulars are extracted from his note book.

† The spot here indicated on the summit of the cliff, is that from which Hamilton's view, plate 26, Campi Phlegræi, is taken, and on which, he observes, Cicero's villa, called the Academia, anciently stood.

marine shells, of species now common on this coast, and amongst them Cardium rusticum, Ostrea edulis, Donax trunculus (Lamk.) and others. The strata vary from about a foot to a foot and half in thickness, and one of them contains abundantly remains of works of art, tiles, squares of mosaic pavement of different colours, and small sculptured ornaments, perfectly uninjured. Intermixed with these I collected some teeth of the pig and ox. These fragments of building occur below as well as above strata containing marine shells. Puzzuoli itself stands chiefly on a promontory of the older tufaceous formation, which cuts off the new deposit, although I detected a small patch of the latter in a garden under the town.

From the town the ruins of a mole, called Caligula's bridge, run out into the sea. This mole consists of a number of piers and arches, and Mr. Babbage found on the fifth pier perforations of lithodomi four feet above the level of the sea, and near the termination of the mole, on the last pier but one, marks of the same, ten feet above the level of the sea, together with great numbers of balani and flustra.

Coast north of Puzzuoli.—If we then pass to the north of Puzzuoli, and examine the coast between that town and Monte Nuovo, we find a repetition of analogous phenomena. The sloping sides of Monte Barbaro slant down within a short distance of the coast, and terminate in an inland cliff of moderate elevation, to which the geologist perceives at once that the sea must, at some former period, have extended. Between this cliff and the sea is a low plain or terrace, called La Starza, corresponding to that before described on the south-east of the town; and, as the sea encroaches rapidly, fresh sections of the strata may readily be obtained, of which the annexed is an example.

Section on the shore north of the town of Puzzuoli:—

	Ft.	In.
1. Vegetable soil	1	0
2. Horizontal beds of pumice and scoriæ, with broken fragments of unrolled bricks, bones of animals, and marine shells	1	6
3. Beds of lapilli, containing abundance of marine shells, prin-		

	Ft.	In.
cipally Cardium rusticum, Donax trunculus, Lam., Ostrea edulis, Triton cutaceum, Lam. and Buccinum serratum Brocchi, the beds varying in thickness from one to eighteen inches	10	0
4. Argillaceous tuff containing bricks and fragments of buildings not rounded by attrition . . .	1	6

The thickness of many of these beds varies greatly as we trace them along the shore, and sometimes the whole group rises to a greater height than at the point above described. The surface of the tract which they compose appears to slope gently upwards towards the base of the old cliffs.

Now if these appearances presented themselves on the eastern or southern coast of England, a geologist would naturally endeavour to seek an explanation in some local depression of high-water mark, in consequence of a change in the set of the tides and currents: for towns have been built, like ancient Brighton, on sandy tracts intervening between the old cliff and the sea, and in some cases they have been finally swept away by the return of the ocean. On the other hand, the inland cliff at Lowestoffe, in Suffolk, remains, as we stated in the fifteenth chapter, at some distance from the shore, and the low green tract called the Ness may be compared to the low flat called La Starza, near Puzzuoli. But there are no tides in the Mediterranean; and to suppose that sea to have sunk generally from twenty to twenty-five feet since the shores of Campania were covered with sumptuous buildings, is an hypothesis obviously untenable. The observations, indeed, made during modern surveys on the moles and cothons (docks) constructed by the ancients in various ports of the Mediterranean, have proved that there has been no sensible variation of level in that sea during the last two thousand years. A very slight change would have been perceptible; and had any been ascertained to have taken place, and had it amounted only to a difference of a few feet, it would not have appeared very extraordinary, since

the equilibrium of the Mediterranean is only restored by a powerful current from the Atlantic *.

Thus we arrive, without the aid of the celebrated temple, at the conclusion, that the recent marine deposit at Puzzuoli was upraised in modern times above the level of the sea, and that not only this change of position, but the accumulation of the modern strata, was posterior to the destruction of many edifices, of which they contain the imbedded remains. If we now examine the evidence afforded by the temple itself, it appears, from the most authentic accounts, that the three pillars now standing erect, continued, down to the middle of the last century, half buried in the new marine strata before described. The upper part of the columns, being concealed by bushes, had not attracted the notice of antiquaries; but, when the soil was removed in 1750, they were seen to form part of the remains of a splendid edifice, the pavement of which was still preserved, and upon it lay a number of columns of African breccia and of granite. The original plan of the building could be traced distinctly; it was of a quadrangular form, seventy feet in diameter, and the roof had been supported by forty-six noble columns, twenty-four of granite, and the rest of marble. The large court was surrounded by apartments, supposed to have been used as bathing-rooms; for a thermal spring, still used for medicinal purposes, issues now just behind the building, and the water, it is said, of this spring, was conveyed by marble ducts into the chambers.

Many antiquaries have entered into elaborate discussions as to the deity to which this edifice was consecrated; but Signor Carelli, who has written the last able treatise on the subject †, endeavours to show that all the religious edifices of Greece were of a form essentially different—that the building, there-

* Captain W. H. Smyth, R. N., obtained, during his survey, numerous proofs of the permanency of the level of the Mediterranean from a remote historical period.

† Dissertazione esergetica sulla sagra Architettura degli Antichi.

fore, could never have been a temple—that it corresponded to the public bathing-rooms at many of our watering-places; and, lastly, that if it had been a temple, it could not have been dedicated to Serapis,—the worship of the Egyptian god being strictly prohibited, at the time when this edifice was in use, by the senate of Rome.

Perforation of the columns by Lithodomous shells.—It is not for the geologist to offer an opinion on these topics, and we shall, therefore, designate this valuable relic of antiquity by its generally received name, and proceed to consider the memorials of physical changes, inscribed on the three standing columns in most legible characters by the hand of nature. (See Frontispiece *.) The pillars are forty-two feet in height; their surface is smooth and uninjured to the height of about twelve feet above their pedestals. Above this is a zone, from nine to twelve feet in height, where the marble has been pierced by a species of marine perforating bivalve—*Lithodomus*, Cuv.† The holes of these animals are pear-shaped, the external opening being minute, and gradually increasing downwards. At the bottom of the cavities, many shells are still found, notwithstanding the great numbers that have been taken out by visitors; in many the valves of a species of arca, an animal which conceals itself in small hollows, occur. The perforations are so considerable in depth and size, that they manifest a long-continued abode of the Lithodomi in the columns; for, as the inhabitant grows older and increases in size, it bores a larger cavity, to correspond with the increasing magnitude of its shell. We must, consequently, infer a long-continued immersion of the pillars in sea-water, at a time when the lower part was covered up and protected by strata of tuff and the rubbish of buildings, the highest part at the same time projecting above

* The representation of the present state of the temple in the frontispiece has been carefully reduced from that given by the Canonico Andrea de Jorio, Ricerche sul Tempio di Serapide, in Puzzuoli. Napoli, 1820.

† Modiola lithophaga, Lam. Mytilus lithophagus, Linn.

the waters, and being consequently weathered, but not materially injured.

On the pavement of the temple, lie some columns of marble, which are perforated in the same manner in certain parts, one, for example, to the length of eight feet, while, for the length of four feet, it is uninjured. Several of these broken columns are eaten into, not only on the exterior, but on the cross fracture, and, on some of them, other marine animals have fixed themselves *. All the granite pillars are untouched by Lithodomi. The platform of the temple is at present about one foot below high-water mark, (for there are small tides in the Bay of Naples,) and the sea, which is only one hundred feet distant, soaks through the intervening soil. The upper part of the perforations then are at least twenty-three feet above high-water mark, and it is clear, that the columns must have continued for a long time in an erect position, immersed in salt-water. After remaining for many years submerged, they must have been upraised to the height of about twenty-three feet above the level of the sea.

Temples and Roman roads under water.—So far the information derived from the temple corroborates that before obtained from the new strata in the plain of La Starza, and proves nothing more. But as the temple could not have been built originally at the bottom of the sea, it must have first sunk down below the waves, and afterwards have been elevated. Of such subsidences there are numerous independent proofs in the Bay of Baiæ. Not far from the shore, to the north-west of the Temple of Serapis, are the ruins of a Temple of Neptune, and a Temple of the Nymphs, now under water. The columns of the former edifice stand erect in five feet water, their upper portions just rising to the surface of the sea. The pedestals are doubtless buried in the mud, so that if this part of the bottom of the bay should hereafter be elevated, the exhumation of this temple might take place after the manner of that of Serapis.

* Serpula contortuplicata, Linn., and Vermilia triquetra, Lam. These species, as well as the Lithodomus, are now inhabitants of the neighbouring sea.

Both these buildings probably participated in the movement which raised the Starza, but, either they were deeper under water than the Temple of Serapis, or they were not raised up again to so great a height. There are also two Roman roads under water in the bay, one reaching from Puzzuoli towards the Lucrine Lake, which may still be seen, and the other near the Castle of Baiæ. The ancient mole, too, of Puzzuoli, before alluded to, has the water up to a considerable height of the arches; whereas Brieslak * justly observes, it is next to certain that the piers must formerly have reached the surface before the springing of the arches: so that, although the phenomena before described prove that this mole has been uplifted ten feet above the level at which it once stood, it is still evident that it has not yet been restored to its original position.

A modern writer also reminds us, that these effects are not so local as some would have us believe; for on the opposite side of the Bay of Naples, on the Sorrentine coast, which, as well as Puzzuoli, is subject to earthquakes, a road, with some fragments of Roman buildings, is covered to some depth by the sea. In the island of Capri, also, which is situated some way at sea, in the opening of the Bay of Naples, one of the palaces of Tiberius is now covered with water †. They who have attentively considered the effects of earthquakes before enumerated by us during the last one hundred and forty years, will not feel astonished at these signs of alternate elevation and depression of the bed of the sea and the adjoining coast during the course of eighteen centuries, but, on the contrary, they will be very much astonished if future researches fail to bring to light similar indications of change in all regions of volcanic disturbances.

Buildings submerged without being destroyed.—That buildings should have been submerged, and afterwards upheaved, without being entirely reduced to a heap of ruins, will appear no

* Voy. dans la Campanie, tome ii. p. 162.

† Mr. Forbes, Physical Notices of the Bay of Naples. Ed. Journ. of Sci., No. II., new series, p. 280. October 1829.

anomaly, when we recollect that in the year 1819, when the delta of the Indus sank down, the houses within the fort of Sindree subsided beneath the waves without being overthrown. In like manner, in the year 1692, the buildings around the harbour of Port Royal, in Jamaica, descended suddenly to the depth of between thirty and fifty feet under the sea without falling. Even on small portions of land transported to a distance of a mile, down a declivity, tenements like those near Mileto, in Calabria, were carried entire. At Valparaiso, buildings were left standing when their foundations, together with a long tract of the Chilian coast, were permanently upraised to the height of several feet in 1822. It is true that, in the year 1750, when the bottom of the sea in the harbour of Penco was suddenly uplifted to the extraordinary elevation of twenty-four feet above its former level, the buildings of that town were thrown down; but we might still suppose that a great portion of them would have escaped, had the walls been supported on the exterior and interior with a deposit, like that which surrounded and filled to the height of ten or twelve feet the Temple of Serapis at Puzzuoli.

Periods when the Temple of Serapis sank and rose.—The next subject of inquiry, is the era when these remarkable changes took place in the Bay of Baiæ. It appears that, in the Atrium of the Temple of Serapis, inscriptions were found in which Septimus Severus and Marcus Aurelius record their labours in adorning it with precious marbles *. We may, therefore, conclude, that it existed at least down to the third century of our era in its original position. On the other hand, we have evidence that the marine deposit forming the flat land called La Starza was still covered by the sea in the year 1530, or just eight years anterior to the tremendous explosion of Monte Nuovo. Mr. Forbes † has lately pointed out the distinct testimony of an old Italian writer Loffredo, in confirmation of this important point. Writing in 1580, Loffredo declares that, fifty

* Brieslak, Voy. dans la Campanie, tom. ii., p. 167.

† Ed. Journ. of Science, new series, No. II., p. 281.

years previously, the sea washed the base of the hills which rise from the flat land before alluded to, and at that time he expressly tells us that a person *might have fished* from the site of those ruins which are now called the Stadium. (See wood cut, No. 30.) Hence it follows, that the subsidence of the ground on which the Temple stood, happened at some period between the third century and the beginning of the sixteenth century.

Now in this interval the only two events which are recorded in the imperfect annals of the dark ages, are the eruption of the Solfatara in 1198, and an earthquake in 1488 by which Puzzuoli was ruined. It is at least highly probable, that earthquakes, which preceded the eruption of the Solfatara, which is very near the Temple, (see wood cut, No. 30) caused a subsidence, and the pumice and other matters ejected from that volcano might have fallen in heavy showers into the sea, and would thus immediately have covered up the lower part of the columns. The action of the waves might afterwards have thrown down many pillars, and formed strata of broken fragments of the building intermixed with volcanic ejections, before the Lithodomi had time to perforate the lower part of the columns. In like manner, the sea, acting on other submerged buildings, would naturally have caused a similar stratum, containing works of art and shells, for several miles along the coast.

Formation of Monte Nuovo.—Now it is perfectly evident, from Loffredo's statement, that the re-elevation of the low tract called La Starza took place after the year 1530, and long before the year 1580; and from this alone we might confidently conclude that the change happened in the year 1538, when Monte Nuovo was formed. But fortunately we are not left in the slightest doubt that such was the date of this remarkable event. Sir William Hamilton* has given us two original letters describing the eruption of 1538, the first of

* Campi Phlegræi, p. 70.

which by Falconi, dated 1538, contains the following passages. 'It is now two years since there have been frequent earthquakes at Puzzuoli, Naples, and the neighbouring parts. On the day and in the night before the eruption (of Monte Nuovo), above twenty shocks, great and small, were felt.—The next morning (after the formation of Monte Nuovo) the poor inhabitants of Puzzuoli quitted their habitations, &c., some with their children in their arms, some with sacks full of their goods, others carrying quantities of birds of various sorts that had fallen dead at the beginning of the eruption, others again with fish which they had found, and which were to be met with in plenty on the shore, the sea having *left them dry for a considerable time.*—I accompanied Signor Moramaldo to behold the wonderful effects of the eruption. The sea had retired on the side of Baiæ, *abandoning a considerable tract,* and the shore appeared almost entirely dry, from the quantity of ashes and broken pumice-stones thrown up by the eruption. I saw two springs *in the newly discovered ruins,* one before the house that was the Queen's, of hot and salt water, &c.'

So far Falconi—the other account is by Pietro Giacomo di Toledo, which begins thus: 'It is now two years since this province of Campagna has been afflicted with earthquakes, the country about Puzzuoli much more so than any other parts: but, the 27th and the 28th of the month of September last, the earthquakes did not cease day or night in the town of Puzzuoli; that plain which lies between lake Avernus, the Monte Barbaro and the sea, was *raised a little,* and many cracks were made in it, from some of which issued water; at the same time the sea immediately adjoining the plain *dried up about two hundred paces,* so that the fish were left on the sand a prey to the inhabitants of Puzzuoli. At last, on the 29th of the same month, about two o'clock in the night, the earth opened, &c.' Now both these accounts, written immediately after the birth of Monte Nuovo, agree in expressly stating, that the sea retired, and one mentions that its bottom was upraised. To this elevation we have already seen that Hooke, writing at the

close of the seventeenth century, alludes as to a well-known fact *. The preposterous theories, therefore, that have been advanced in order to dispense with the elevation of the land, in the face of all this historical and physical evidence, are not entitled to a serious refutation.

Encroachments of the sea in the Bay of Baiæ.—The flat land, when first upraised, must have been more extensive than now, for the sea encroaches somewhat rapidly, both to the north and south-east of Puzzuoli. The coast has of late years given way more than a foot in a twelvemonth, and I was assured by fishermen in the bay, that it has lost ground near Puzzuoli, to the extent of thirty feet, within their memory. It is, probably, this gradual encroachment which has led many authors to imagine that the level of the sea is slowly rising in the Bay of Baiæ, an opinion by no means warranted by such circumstances. In the course of time the whole of the low land will, perhaps, be carried away, unless some earthquake shall remodify the surface of the country, before the waves reach the ancient coast-line; but the removal of this narrow tract will by no means restore the country to its former state, for the old tufaceous hills and the interstratified current of trachytic lava which has flowed from the Solfatara, must have participated in the movement of 1538; and these will remain upraised even though the sea may regain its ancient limits.

In 1828 excavations were made below the marble pavement of the Temple of Serapis, and another costly pavement of mosaic was found, at the depth of five feet or more below the other. The existence of these two pavements at different levels seems clearly to imply some subsidence previously to all the changes already alluded to, which had rendered it necessary to construct a new floor at a higher level. But to these and other circumstances bearing on the history of the Temple antecedently to the revolutions already explained, we shall not refer at present, trusting that future investigations will set them in a clearer light.

* Ante, p. 39.

Permanence of the Ocean's level.—In concluding this subject, we may observe, that the interminable controversies to which the phenomena of the Bay of Baiæ gave rise, have sprung from an extreme reluctance to admit that the land rather than the sea is subject alternately to rise and fall. Had it been assumed that the level of the ocean was invariable, on the ground that no fluctuations have as yet been clearly established, and that, on the other hand, the continents are inconstant in their level, as has been demonstrated by the most unequivocal proofs again and again, from the time of Strabo to our own times, the appearances of the Temple at Puzzuoli could never have been regarded as enigmatical. Even if contemporary accounts had not distinctly attested the upraising of the coast, this explanation should have been proposed in the first instance as the most natural, instead of being now adopted unwillingly when all others have failed.

To the strong prejudices still existing in regard to the mobility of the land we may attribute the rarity of such discoveries as have been recently brought to light in the Bay of Baiæ and the Bay of Conception. A false theory it is well known may render us blind to facts, which are opposed to our prepossessions, or may conceal from us their true import when we behold them. But it is time that the geologist should in some degree overcome those first and natural impressions which induced the poets of old to select the rock as the emblem of firmness—the sea as the image of inconstancy. Our modern poet, in a more philosophical spirit, saw in the latter 'The image of Eternity,' and has finely contrasted the fleeting existence of the successive empires which have flourished and fallen on the borders of the ocean, with its own unchanged stability.

——— Their decay
Has dried up realms to deserts:—not so thou,
Unchangeable, save to thy wild waves' play:
Time writes no wrinkle on thine azure brow;
Such as creation's dawn beheld, thou rollest now.

CHILDE HAROLD, Canto iv.

CHAPTER XXVI.

Subterranean changes at great depths below the surface indicated by earthquakes —Obscurity of geological phenomena no proof of want of uniformity in the system, because subterranean processes are but little understood—Reasons for presuming the earthquake and volcano to have a common origin—Probable analogy between the agency of steam in the Icelandic geysers, and in volcanos during eruptions—Effects of hydrostatic pressure of high columns of lava—Of the condensation of vapours in the interior of the earth—That some earthquakes may be abortive eruptions—Why all volcanos are in islands or maritime tracts —Gases evolved from volcanos—Regular discharge of heat and of gaseous and earthy matter from the subterranean regions—Cause of the wave-like motion and of the retreat of the sea during earthquakes—Difference of circumstances of heat and pressure at great depths—Inferences from the superficial changes brought about by earthquakes—In what manner the repair of land destroyed by aqueous causes takes place—Proofs that the sinking in of the earth's crust somewhat exceeds the forcing out by earthquakes—Geological consequences of this hypothesis—No ground for presuming that the degree of force exerted by subterranean movements in a given time has diminished—Concluding remarks.

Subterranean changes at great depths below the surface indicated by earthquakes.—When we consider attentively the changes brought about by earthquakes during the last century, and reflect on the light which they already throw on the ancient history of the globe, we cannot but regret that investigations into the effects of this powerful cause have hitherto been prosecuted with so little zeal. The disregard of this important subject may be attributed to the general persuasion, that former revolutions of the earth were not brought about by causes now in operation,—a theory which, if true, would fully justify a geologist in neglecting the study of such phenomena. We may say of the superficial alterations arising from subterranean movements, as we have already declared of the visible effects of active volcanos, that, important as they are in themselves, they are still more so as indicative of far greater changes in the interior of the earth's crust. That both the chemical and

mechanical changes in the subterranean regions must often be of a kind to which no counterpart can possibly be found in progress within the reach of our observation, may be confidently inferred; and speculations on these subjects ought not to be discouraged, since a great step is gained if they render us more conscious of the extent of our inability to define the amount and kind of results to which ordinary subterranean operations are now giving rise.

It is no longer disputed that a great series of convulsions have carried up deposits once formed on the bottom of the ocean to the height of several miles above its level; and it is not difficult to perceive that the same movements must in numerous places have raised rocks to elevations above the level of the sea, which were once formed at the depth of several miles in the bowels of the earth. If, then, there were no spots discoverable which exhibited signs of extraordinary mechanical and chemical changes, the effects at some former period of immense pressure, intense heat, and other conditions far different from those developed on the surface, it might be urged as a triumphant argument against those who are dissatisfied with the proofs hitherto adduced in favour of the mutability of the course of Nature.

In order to set this in a clear light, let the reader suppose himself acquainted with just one-tenth part of the words of some living language, and that he is presented with several books purporting to be written in the same tongue ten centuries ago. If he should find that he comprehends a tenth part of the terms in the ancient volumes, and that he cannot divine the meaning of the other nine-tenths, would he not be strongly disposed to believe that, for a thousand years, the language has remained *unaltered?* Could he, without great labour and study, interpret the greater part of what is written in the antique documents, he must feel at once convinced that, in the interval of ten centuries, a great revolution in the language had taken place. He might, undoubtedly, by comparing the conventional signs already known to him with those not pre-

viously acquired, and by observing the analogies and associations of terms in many of the old books, come at length to discover the true import of much of the ancient writings, and guess at the meaning of nearly all the rest; but if he is entirely shut out from all communication with those who now use the same language, he will never fully understand the value of some terms.

So, if a student of Nature, who, when he first examines the monuments of former changes upon our globe, is acquainted only with one-tenth part of the processes now going on upon or far below the surface, or in the depths of the sea, should still find that he comprehends at once the import of the signs of all, or even half the changes that went on in the same regions some hundred or thousand centuries ago, he might declare without hesitation that the ancient laws of nature have been subverted. Even after toiling for centuries, and learning more both of the present and former state of things, he must never expect to gain a perfect insight into all that formerly happened, so long as his acquaintance is very limited in regard to much that is now going on. So completely has the force of this line of argument been overlooked, that when any one has ventured to presume that all former changes were simply the result of causes now in operation, he has invariably been called upon to explain every obscure phenomenon in geology, and, if he has failed, it has been considered as conclusive against his assumption. Whereas, in truth, there is no part of the evidence in favour of the uniformity of the system more cogent than the fact that, with much that is intelligible, there is still more which is yet novel, mysterious, and inexplicable, in the monuments of ancient mutations in the earth's crust.

Ancient theories as to the causes of Earthquakes.—Before the immense depth of the sources of volcanic fire was generally admitted, the causes of subterranean movements were sought in peculiar states of the atmosphere. These were imagined to afford not only prognostics of the convulsions, but to have

considerable influence in their production. But the supposed signs of approaching earthquakes were of a most uncertain and contradictory character. Aristotle, Pliny, and Seneca taught that earthquakes were preceded by a serene state of the air; whereas several modern writers have been of opinion that a cloudy sky and sudden storms are the forerunners of these commotions. That there is an intimate connexion between subterranean convulsions and particular states of the weather is unquestionable; but, as Michell truly remarked, 'it is more probable that the air should be affected by the causes of earthquakes, than that the earth should be affected in so extraordinary a manner, and to so great a depth, by a cause residing in the air.'

After violent earthquakes the regular drainage of a country is obstructed; lakes and pools are caused by local subsidences or landslips, and the evaporation of an extensive surface of shallow water produces unseasonable rains. Fogs proceed from the damp soil which is traversed by numerous rents and crevices filled with water. In addition to these circumstances, the electrical effect produced by the movement and friction of great masses of rock against each other may cause lightning, gusts of wind, luminous exhalations, and other atmospheric phenomena. Rains, moreover, are sometimes derived from volcanic eruptions accompanying earthquakes; for eruptions, as we before stated, are attended with a copious discharge of aqueous vapour.

Reasons for presuming the Earthquake and Volcano to have a common origin.—Before we attempt to inquire further into the true causes of earthquakes, we shall briefly recapitulate our reasons for considering them as originating from the same sources as volcanic phenomena. In the first place, the regions convulsed by violent earthquakes include within them the site of all the active volcanos. Earthquakes, sometimes local, sometimes extending over vast areas, precede volcanic eruptions. Both the subterranean movement and the eruption return again and again, at unequal intervals of time, and with

unequal degrees of force, to the same places. The duration of both may continue for a few hours, or for several consecutive years. Paroxysmal convulsions of both kinds are usually followed by long periods of tranquillity. Thermal springs, and those containing abundance of mineral matter in solution, are characteristic of countries where active volcanos or earthquakes are frequent. In districts considerably distant from volcanic vents, the temperature of hot springs has been sometimes raised by subterranean movements.

In addition to these signs of relation and analogy, we may observe that it is not very easy to conceive how columns of melted matter can be raised to such great heights as we know them to attain in volcanos, without exerting an hydrostatic pressure capable of moving enormous masses of land; nor can we be surprised that elastic fluids capable of forcing up so great a weight of rock in fusion, and of projecting large stones to immense heights in the air, should also cause tremors, vibrations, and violent movements in the solid crust of the earth. The volcano of Cotopaxi has thrown a mass of rock, about one hundred cubic yards in volume, to the distance of eight or nine miles, and we may well conceive that the slightest obstruction to the escape of such an expansive force may convulse a considerable tract in South America. 'If these vapours,' says Michell, 'when they find a vent, are capable of shaking a country to the distance of ten or twenty miles round the volcano, what may we not expect from them when they are confined?'

Geysers of Iceland.—As there is no doubt that aqueous vapour constitutes the most abundant of the aëriform products of volcanic eruptions, it may be well to consider attentively a case in which steam is exclusively the moving power—the Geysers of Iceland. These intermittent hot springs rise from a large tract, covered to a considerable depth by a stream of lava, and where thermal waters and apertures evolving steam are very common. The great Geyser rises out of a spacious basin at the summit of a circular mound, composed of siliceous

incrustations deposited from the spray of its waters. The diameter of the basin or crater, in one direction, is fifty-six feet, and forty-six in another.

No. 33.

*View of the Crater of the great Geyser in Iceland**.

In the centre is a pipe seventy-eight feet in perpendicular depth, and from eight to ten feet in diameter, but gradually widening as it opens into the basin. The inside of the basin is whitish, consisting of a siliceous incrustation, and perfectly smooth, as are two small channels on the sides of the mound, down which the water makes its escape when filled to the margin. The circular basin is sometimes empty, as represented in the above sketch, but is usually filled with beautifully transparent water in a state of ebullition. During the rise of the boiling water up the pipe, especially when the ebullition is most violent, and when the water flows over or is thrown up in jets, subterranean noises are heard, like the distant firing of cannon, and the earth is slightly shaken. The sound then increases and the motion becomes more violent, until at length a column of water is thrown up perpendicularly with loud explosions, to the height of one or two hundred feet. After playing for a time like an artificial fountain, and giving off

* Reduced from a sketch given by W. J. Hooker, M.D., in his 'Tour in Iceland,' vol. i. p. 149.

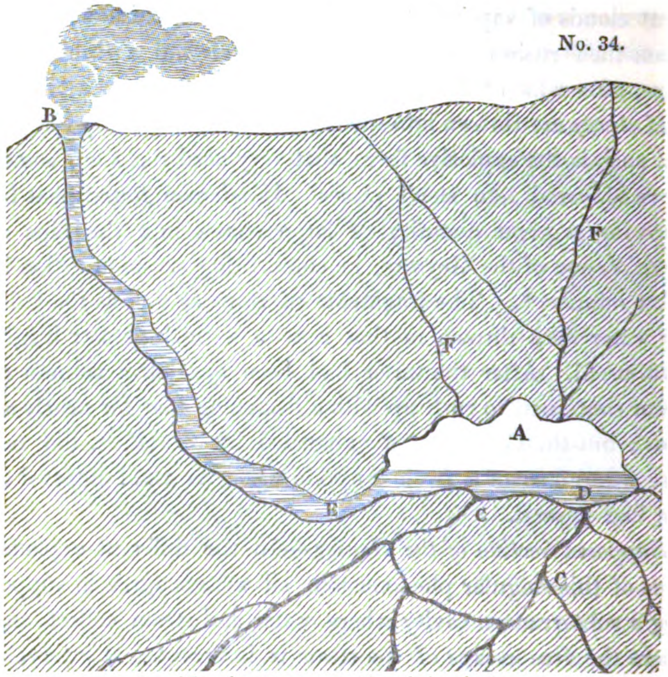
great clouds of vapour, the pipe is evacuated, and a column of steam then rushes up with amazing force and a thundering noise, after which the eruption terminates.

If stones are thrown into the crater they are instantly ejected, and such is the explosive force, that very hard rocks are sometimes shivered into small pieces. Henderson found that by throwing a great quantity of large stones into the pipe of Strockr, one of the Geysers, he could bring on an eruption in a few minutes *. The fragments of stone as well as the boiling water were thrown in that case to a much greater height than usual. After the water had been ejected, a column of steam continued to rush up with a deafening roar for nearly an hour; but the Geyser, as if exhausted by this effort, did not give symptoms of a fresh eruption when its usual interval of rest had elapsed.

Supposed section of the Geyser.—In the different explanations of this singular phenomenon, all writers agree in supposing a subterranean cavity where water and steam collect, and where the free escape of the steam is intercepted at intervals, until it acquires sufficient force to discharge the water. Suppose water percolating from the surface of the earth to penetrate into the subterranean cavity A D by the fissures F F, while, at the same time, steam, at an extremely high temperature, such as is commonly given out from the rents of lava-currents during congelation, emanates from the fissures C C. A portion of the steam is at first condensed into water, and the temperature of the water is raised by the latent heat evolved, until, at last, the lower part of the cavity is filled with boiling water and the upper with steam under high pressure. The expansive force of the steam becomes, at length, so great, that the boiling water is forced up the fissure or pipe E B, and a considerable quantity runs over the rim of the basin. When the pressure is thus diminished, the steam in the upper part of the cavity A expands until all the water D is driven to E;

* Journal of a Residence in Iceland, p. 74.

No. 34.



Supposed section of the subterranean reservoir and pipe of a Geyser in Iceland *.

when this happens, the steam, being the lighter of the two fluids, rushes up with great velocity, as on the opening of the valve of a steam-boiler. If the pipe be choked up artificially with stones, even for a few minutes, a great increase of heat must take place, for it is prevented from escaping in a latent form in steam, so that the water is made to boil up in a few minutes, and this brings on an eruption.

Hydrostatic pressure of lava.—Now if we suppose a great number of large subterranean cavities at the depth of several miles below the surface of the earth, wherein melted lava accumulates, and that water penetrating to these is converted into steam, this steam, together with other gases generated by the decomposition of melted rocks, may press upon the lava and force it up the duct of a volcano, in the same manner as it drives a column of water up the pipe of a Geyser. But the

* From Sir George Mackenzie's Iceland.

weight of the lava being immense, the hydrostatic pressure exerted on the sides and roofs of such large cavities and fissures may well be supposed to occasion not merely slight tremors, such as agitate the ground before an eruption of the Geyser, but violent earthquakes. Sometimes the lateral pressure of the lower extremity of the high column of lava may cause the more yielding strata to give way, and to fold themselves in numerous convolutions, so as to occupy less space, and thereby give relief, for a time, to the fused and dilated matter. Sometimes, on the contrary, a weight equal to that of the vertical column of lava, pressing on every part of the roof, may heave up the superincumbent mass, and force lava into every fissure which, on consolidation, may support the arch, and cause the land above to be permanently elevated. On the other hand, subsidences may follow the condensation of vapour when cold water descends through fissures, or when heat is lost by the cooling down of lava.

Cause of lateral eruptions.—That lava should often break out from the side or base, rather than from the summit of a lofty cone like Etna, has always been attributed to the immense hydrostatic pressure which the sides of the mountain undergo, before the lava can rise to the crater. This conclusion is too obvious not to have met with a general reception; yet how trifling must this pressure be when compared to that which the same column imparts to the reservoirs of aëriform fluids and melted rock, at the depth of many miles or leagues below the surface!

And of earthquakes.—If earthquakes be derived from the expansion by heat of elastic fluids and melted rock, it is perfectly natural that they should terminate, either when a volcanic vent permits a portion of the pent up vapours or lava to escape, or when the earth has been so fissured that the vapour is condensed by its admission into cooler regions, or by its coming in contact with water. Or relief may be obtained when lava and gaseous fluids have, by distending the strata, made more room for themselves, so that the weight of the superin-

cumbent mass is sufficient to repress them. If we regard earthquakes as abortive volcanic eruptions at a great depth, we must expect them to succeed each other for an indefinite number of times in the same place, for the same reasons that eruptions do; and it is easy to conceive that, if the matter has failed several times to reach the surface, the consolidation of the lava first raised and congealed will strengthen the earth's crust, and become an additional obstacle to the protrusion of other fused matter during subsequent convulsions.

Gases evolved from volcanos.—Volcanos exhale, during eruptions, besides aqueous vapour, the following gases: muriatic acid, sulphur combined with hydrogen or oxygen, carbonic acid and nitrogen, the greater part of which would result from the decomposition of salt-water, a fact which, when taken in conjunction with the proximity of nearly two hundred active vents to the sea, and their absence, with few exceptions, in the interior of large continents, is almost conclusive as to the co-operation of water and fire in the raising of lava to the surface.

Why most volcanos in islands or maritime tracts.—Some even of those few volcanos which lie inland form part of a chain of volcanic hills, and may be supposed to have a subterranean communication with the extremities of the chain which are in the neighbourhood of large masses of salt-water. Thus Jorullo, in Mexico, though itself no less than forty leagues from the nearest ocean, seems, nevertheless, connected with the volcano of Tuxtla on the one hand, and that of Colima on the other, the one bordering on the Atlantic, the other on the Pacific ocean. This communication is rendered the more probable by the parallelism that exists between these and several volcanic hills intermediate *.

Volcanic action considered in its most extended sense, so as to include earthquakes, is not perhaps more energetic in that part of the globe which is covered by water, than in that

* See Daubeny's remarks on this subject,—" Volcanos," p. 368.

which has become dry land; but *eruptions* are more common in or near the sea than in the interior of continents. Earthquakes may very probably imply the generation of lava in the nether regions, and they appear to prevail as much under the surface of the dry land as under the sea, or in maritime regions. The access, therefore, of sea-water is not a primary cause of volcanic agency, but the proximity of great bodies of water to reservoirs of liquid lava may give rise to violent explosions, masses of water being swallowed up (just as trees and houses are engulphed) in fissures, and suddenly converted into steam, which, bursting through the superincumbent rocks, may open a passage for the ascent of lava.

We have before suggested the great probability that, in existing volcanic regions, there are enormous masses of matter in a constant state of fusion far below the surface: this opinion is confirmed by numerous phenomena. Perennial supplies of hot vapour and aëriform fluids rise to certain craters, as in Stromboli for example, and Nicaragua, which are in a state of ceaseless eruption. Sangay in Quito, Popocatepetl in Mexico, and the volcano of the isle of Bourbon, have continued in incessant activity for periods of sixty or one hundred and fifty years. Numerous solfataras, evolving the same gases as volcanos, serve as permanent vents of heat generated in the subterranean regions. The plentiful evolution, also, of carbonic acid, from springs and fissures throughout hundreds of square leagues, is another regular source of communication between the interior and the surface. Steam, often above the boiling temperature, is emitted for ages without intermission from "stufas," as the Italians term them. Hot springs in great numbers, especially in tracts where earthquakes are frequent, serve also as regular conductors of heat from the interior upwards. Silex, carbonate of lime, muriate of soda, and many earths, alkalies, and metals are poured out in a state of solution by springs, and the solid matter which is tranquilly removed in this manner may, perhaps, exceed that which issues in the shape of lava.

It is to the efficacy of this ceaseless discharge of heat, and of solid as well as gaseous matter, that we probably owe the general tranquillity of our globe; for were it not that some kind of equilibrium is established between fresh accessions of heat and its discharge, we might expect perpetual convulsions, if we conceive the land and the ocean itself to be incumbent in many extensive districts on subterranean reservoirs of lava. If there be reason for wonder, it is, as Pliny observed, that a single day should pass without some dreadful explosion; 'Excedit profectò omnia miracula, ullum diem fuisse quo non cuncta conflagrarent *.' But the circulation of heat from the interior to the surface, is probably regulated like that of water from the continents to the sea, in such a manner that it is only when some obstruction occurs to the regular discharge, that the usual repose of Nature is broken. Any interruption to the regular drainage of a country causes a flood, and, if there be any obstruction in the passages by which volcanic matter continually rises, an earthquake or a paroxysmal eruption is the consequence.

Cause of the wave-like motion during earthquakes.—Michell has observed, that the wave-like motion of the ground during earthquakes, appears less extraordinary if we call to mind the extreme elasticity of the earth, and that even the most solid materials are easily compressible. If we suppose large districts to rest upon the surface of subterranean lakes of melted matter, through which violent motions are propagated, it is easy to conceive that superincumbent solid masses may be made to vibrate or undulate. The following ingenious speculations are suggested by the above-mentioned writer. 'As a small quantity of vapour almost instantly generated at some considerable depth below the surface of the earth will produce a vibratory motion, so a very large quantity (whether it be generated almost instantly, or in any small portion of time) will produce a wave-like motion. The manner in which this wave-like motion will be propagated may in some measure be represented

* Hist. Mundi, lib. ii. c. 107.

by the following experiment. Suppose a large cloth, or carpet (spread upon a floor) to be raised at one edge, and then suddenly brought down again to the floor, the air under it being by this means propelled, will pass along, till it escapes at the opposite side, raising the cloth in a wave all the way as it goes. In like manner, a large quantity of vapour may be conceived to raise the earth in a wave, as it passes along between the strata which it may easily separate in an horizontal direction, there being little or no cohesion between one stratum and another. The part of the earth that is first raised, being bent from its natural form, will endeavour to restore itself by its elasticity, and the parts next to it being to have their weight supported by the vapour, which will insinuate itself under them, will be raised in their turn, till it either finds some vent, or is again condensed by the cold into water, and by that means prevented from proceeding any farther *.'

To this hypothesis of Michell it has been objected with some reason, that the wave-like movements of the surface of the land during earthquakes, though violent, are on a very minute scale, as appears from the account of tall trees whipping their tops against the ground on either side, the sea-sickness experienced by spectators, and other phenomena clearly indicating the small radius of each superficial curvature. On the other hand, the sudden fracture, it is said, of solid strata might produce a vibratory jar, which being propagated in undulations through a mass of rock several thousand feet thick, would give rise to such superficial waves as are described, even though the subjacent crust of the globe were entirely solid, and neither reposing on fluid nor gaseous matter †.

Cause of the retreat of the sea during earthquakes.—In order to account for the retreat of the ocean from the shores before or during an earthquake, Michell imagines a subsidence at the bottom of the sea, from the giving way of the roof of

* On the Cause and Phenomena of Earthquakes, Phil. Trans., vol. li. sec. 58. 1760.

† Quarterly Review, No. lxxxvi. p. 463.

some cavity in consequence of a vacuum produced by the condensation of steam. For such condensation, he observes, might be the first effect of the introduction of a large body of water into fissures and cavities already filled with steam, before there has been sufficient time for the heat of the incandescent lava to turn so large a supply of water into steam, which being soon accomplished causes a greater explosion. Sometimes the rising of the coast must give rise to the retreat of the sea, and the subsequent wave may be occasioned by the subsiding of the shore to its former level; but this will not always account for the phenomena. During the Lisbon earthquake, for example, the retreat preceded the wave not only on the coast of Portugal, but also at the island of Madeira and several other places. If the upheaving of the coast of Portugal had caused the retreat, the motion of the waters when propagated to Madeira would have produced a wave previous to the retreat. Nor could the motion of the waters at Madeira have been caused by a different local earthquake, for the shock travelled from Lisbon to Madeira in two hours, which agrees with the time which it required to reach other places equally distant *.

The following explanation of the desertion of the coast by the sea, and its immediate return in a terrific wave, has been offered. If a portion of the bed of the sea be suddenly upheaved, the first effect will be to raise over the elevated part a body of water, the momentum of which will carry it much above the level it will afterwards assume, causing a draught or receding of the water from the neighbouring coasts, followed immediately by the return of the displaced water, which will also be impelled by its momentum much farther and higher on the coast than its former level †.

Difference of circumstances of heat and pressure at great depths.—We shall not indulge at present in further speculations on the mode whereby subterranean heat may give rise to

* Michell, Phil. Trans., vol. li. p. 614.

† Quarterly Review, No. lxxxvi. p. 459.

the phenomena of earthquakes and volcanos. No one, however, can fail to be convinced, if he turns his thoughts to the subject, that a great part of the reasoning of the most profound natural philosophers and chemists can be regarded as little more than mere conjecture on matters where the circumstances are so far removed from those which fall under actual observation. Many processes must be carried on in situations where the pressure exceeds as much that produced by the weight of the loftiest mountains, as the weight of the unfathomed ocean surpasses that of the atmosphere. The mechanical effects, therefore, of earthquakes at vast depths, may be such as can never be paralleled on the surface. The intensity of heat must often be so far removed from that which we can imitate by experiments, that the elements of solid rocks or fluids may enter into combinations such as can never take place within the limited range of our observations. Water at a certain depth may, as Michell boldly suggested, become incandescent without expanding, and remain at rest without any tendency to produce an earthquake. Air, if it ever penetrate to such depths, may become a fluid. Sir James Hall's experiments prove, that, under a pressure of about one thousand seven hundred feet of sea, corresponding to that of only six hundred feet of liquid lava, limestone melts without giving off its carbonic acid, so that it is only when calcareous lavas are forced up to within a slight distance of the surface, or into a sea of moderate depth, that the carbonic acid begins to assume a gaseous form, and to assist in bringing on a volcanic eruption.

Inferences from the superficial changes brought about by Earthquakes.—But let us now turn our attention to those superficial changes brought about by so many of the earthquakes within the last century and a half, before described. Besides the undulatory movements, and the opening of fissures, it was shown that certain parts of the earth's crust, often of considerable area, both above and below the level of the sea, have been permanently elevated or depressed; examples of elevation by single earthquakes having occurred, to the amount

of from one to about twenty-five feet, and of subsidence from a few inches to about fifty feet, exclusively of those limited tracts, as the forest of Aripao, where a sinking down to the amount of three hundred feet took place. It is evident, that the force of subterranean movement does not operate at random, but that the same continuous tracts are agitated again and again; and however inconsiderable may be the alterations produced during a period sufficient only for the production of ten or fifteen eruptions of an active volcano, it is obvious that, in the time required for the formation of a lofty cone, composed of thousands of lava currents, shallow seas may be converted into lofty mountains, and low lands into deep seas.

We need, therefore, cherish none of the apprehensions entertained by Buffon, that the inequalities of the earth's surface, or the height and area of our continents, will be reduced by the action of running water; nor need we participate in the wonder of Ray, that the dry land should not lose ground more rapidly. Neither need we anticipate with Hutton the waste of successive continents followed by the creation of others by paroxysmal convulsions.

The renovating as well as the destroying causes are unceasingly at work, the repair of land being as constant as its decay, and the deepening of seas keeping pace with the formation of shoals. If, in the course of a century, the Ganges and other great rivers have carried down to the sea a mass of matter equal to many lofty mountains, we also find that a district in Chili, one hundred thousand square miles in area, has been uplifted to the average height of a foot or more, and the cubic contents of the granitic mass thus added in a few hours to the land, may have counterbalanced the loss effected by the aqueous action of many rivers in a century. On the other hand, if the water displaced by fluviatile sediment cause the mean level of the ocean to rise in a slight degree, such subsidences of its bed, as that of Cutch in 1819, or St. Domingo in 1751, or Jamaica in 1692, may have compensated by increasing the capacity of the great oceanic basin. No river can push forward its delta with-

out raising the level of the whole ocean, although in an infinitesimal degree; and no lowering can take place in the bed of any part of the ocean, without a general sinking of the water, even to the antipodes.

If the separate effects of different agents, whether aqueous or igneous, are insensible, it is because they are continually counteracted by each other, and a perfect adjustment takes place before any appreciable disturbance is occasioned. How many considerable earthquakes there may be upon an average in the course of one year, throughout the whole globe, is a question that we cannot decide at present; but as we have calculated that there are about twenty volcanic eruptions annually, we shall, perhaps, not overrate the earthquakes, if we estimate their number to be equal. A large number of eruptions are attended by local earthquakes of sufficient violence to modify the surface in some slight degree, and there are many earthquakes, on the other hand, not followed by eruptions. Even if we do not assume, as many have done, that the submarine convulsions exceed in number and violence those on the land, in spaces of equal area, we must, nevertheless, reckon about three shocks exclusively submarine, for one exclusively confined to the continents.

Repair of land destroyed by aqueous causes.—We have said in a former chapter* that the aqueous and igneous agents may be regarded as antagonist forces, the aqueous labouring incessantly to reduce the inequalities of the earth's surface to a level, while the igneous are equally active in restoring the unevenness of the crust of the globe. But an erroneous theory appears to have been entertained by many geologists, and is indeed as old as the time of Lazzaro Moro, that the levelling power of running water was opposed rather to the *elevating* force of earthquakes than to their action generally. To such an opinion the numerous well-attested facts of subsidences must always have appeared a serious objection, but the same hypothesis would lead to other assumptions of a very arbitrary and improbable kind,

* Chap. x. p. 192.

inasmuch as it would be necessary to imagine the magnitude of our planet to be always on the increase if the elevation of the earth's surface by subterranean movements exceeded the depression. The sediment carried into the depths of the sea by rivers, tides, and currents, tends to diminish the height of the land; but, on the other hand, it tends, in a degree, to augment the height of the ocean, since water, equal in volume to the matter carried in, is displaced.

The mean distance, therefore, of the surface, whether occupied by land or water from the centre of the earth, remains unchanged by the action of rivers, tides, and currents. Now suppose that while these agents are destroying islands and continents, the restoration of land should take place solely by the forcing out of the earth's envelope—it will be seen that this would imply a continual distension of the whole mass of the earth. For the greater number of earthquakes would be submarine, and they would cause the sea to rise and submerge the low lands even in a greater degree than would the influx of sediment. Two causes would, therefore, tend to destroy the land; submarine earthquakes, and the destroying and transporting power of water; and in order to counterbalance these effects, shallow seas must be upraised into continents, and low lands into mountains.

Proofs that the amount of subsidence exceeds that of elevation.—If we first consider the question simply, in regard to the manner whereby earthquakes may prevent running water from altering the relative proportion of land and sea, or the height of the land and depth of the ocean, we shall find that if the rising and sinking be equal, things would remain upon the whole in the same state: because rivers, tides, and currents add as much to the height of lands which are rising, as they take from those which have risen.

Suppose a large river to carry down sediment into a certain part of the ocean where there is a depth of two thousand feet, and that the whole space is reduced by the fluviatile depositions to a shoal only covered by water at high tide: then let

a series of two hundred earthquakes strike the shoal, each raising the ground ten feet; the result will be a mountain two thousand feet high. But suppose the same earthquakes had visited the same hollow in the bottom of the sea before the sediment of the river had filled it up, their whole force would then have been expended in converting a deep sea into a shoal, instead of changing a shoal into a mountain two thousand feet high. The superior altitude, then, of a district may often be due to the transportation of matter at a former period *to lower levels*.

It would probably be more consistent with the natural course of events, if, instead of a succession of elevatory movements, we were to suppose considerable oscillations before the district attained its full height. Let there be, for example, three hundred instead of two hundred shocks, each separated from the other by intervals of about fifty years. Let the mean alteration of level produced by each earthquake be ten feet, two hundred and fifty shocks causing a rise, and the other fifty a sinking in of the ground; although more time will have been consumed by this operation than by the former, we shall still have the same result, for a tract will be raised to the height of about two thousand feet. The chief difference will consist in the superior breadth and depth of the valleys, which will be greater nearly in the proportion of one-third, in consequence of the number of landslips, floods, opening of chasms, and other effects produced by one hundred additional earthquakes. It should be borne in mind, moreover, that some of the lowering movements, happening towards the close of the period of disturbance, may have given rise to strange anomalies, should an attempt be made to reconcile the whole excavation in various hydrographical basins to the levels finally retained. Perhaps, for example, the middle portion of a valley may have sunk down, so that a deep lake may intervene between mountains and certain low plains, to which their debris had been previously carried.

But to return to the consideration of the proportion between

the elevation and depression of the earth's crust, which may be necessary to preserve the uniformity of the general relations of land and sea, on the surface. The circumstances are in truth more complicated than those before stated, for, independently of the transfer of matter by running water from the continents to the ocean, there is a constant transportation of mineral ingredients from below upwards, by mineral springs and volcanic vents. As mountain masses are in the course of ages created by the pouring forth of successive streams of lava, so others originate from the carbonate of lime and other mineral ingredients with which springs are impregnated. The surface of the land, and parts of the bottom of the sea are thus raised, and if we conceive the dimensions of the planet to remain uniform, we must suppose these external accessions to be counteracted by some action of an opposite kind. A considerable quantity of earthy matter may sink down into fissures caused by earthquakes, but this cannot be deemed sufficient to counterbalance the addition of mountain masses by the causes before adverted to, and we must therefore suppose, that the subsidences of the earth's crust exceed the elevations caused by subterranean movements.

It is to be expected, on mechanical principles, that the constant subtraction of matter from the interior will cause vacuities, so that the surface undermined will fall in during convulsions which shake the earth's crust even to great depths, and the sinking down will be occasioned partly by the hollows left when portions of the solid crust are heaved up, and partly when they are undermined by the subtraction of lava and the ingredients of decomposed rocks.

Geological consequences of this hypothesis.—The geological consequences which will follow if we embrace the theory now proposed are very important, for if there be upon the whole more subsidence than elevation, then we must consider the depth to which former surfaces have sunk down beneath their original level, to exceed the height which ancient marine strata have attained above the sea. If, for example, marine strata about

the age of our chalk and green-sand have been lifted up in Europe to an extreme elevation of more than eleven thousand feet, and to a mean height of some hundreds above the level of the sea, we may conclude that certain parts of the earth's surface, which existed whether above or below the waters when those strata were deposited, have subsequently sunk down to an extreme depth of *more than* eleven thousand feet below their original level, and to a mean depth of *more than* a few hundreds.

In regard to faults, also, we must, according to the hypothesis now proposed, infer that a greater number have arisen from the sinking down than from the elevation of rocks. If we find, therefore, ancient deposits full of fresh-water remains, which evidently originated in a delta or shallow estuary, covered subsequently by purely marine formations of vast thickness, we shall not be surprised; for we must expect that a greater number of existing deltas and estuary formations will sink below, than those which will rise above their present level. Although it would be rash to attempt to confirm these speculations by reference to the scanty observations hitherto made on the effects of earthquakes, yet we cannot but remark, that the instances of subsidence on record are far more numerous than are those of elevation.

No ground for presuming that subterranean movements have decreased in violence.—Those writers who have most strenuously contended for the analogy of the effects of earthquakes in ancient and modern times, have nevertheless declared that the energy of the force has considerably abated. But they do not appear to have been aware that, in order to adduce plausible grounds for such an hypothesis, they must possess a most extensive knowledge of the economy of the whole terrestrial system. We can only estimate the relative amount of change produced at two distinct periods, by a particular cause in a given lapse of time, when we have obtained some common standard for the measurement of equal portions of time at both periods. We have shown that, within the last one hundred

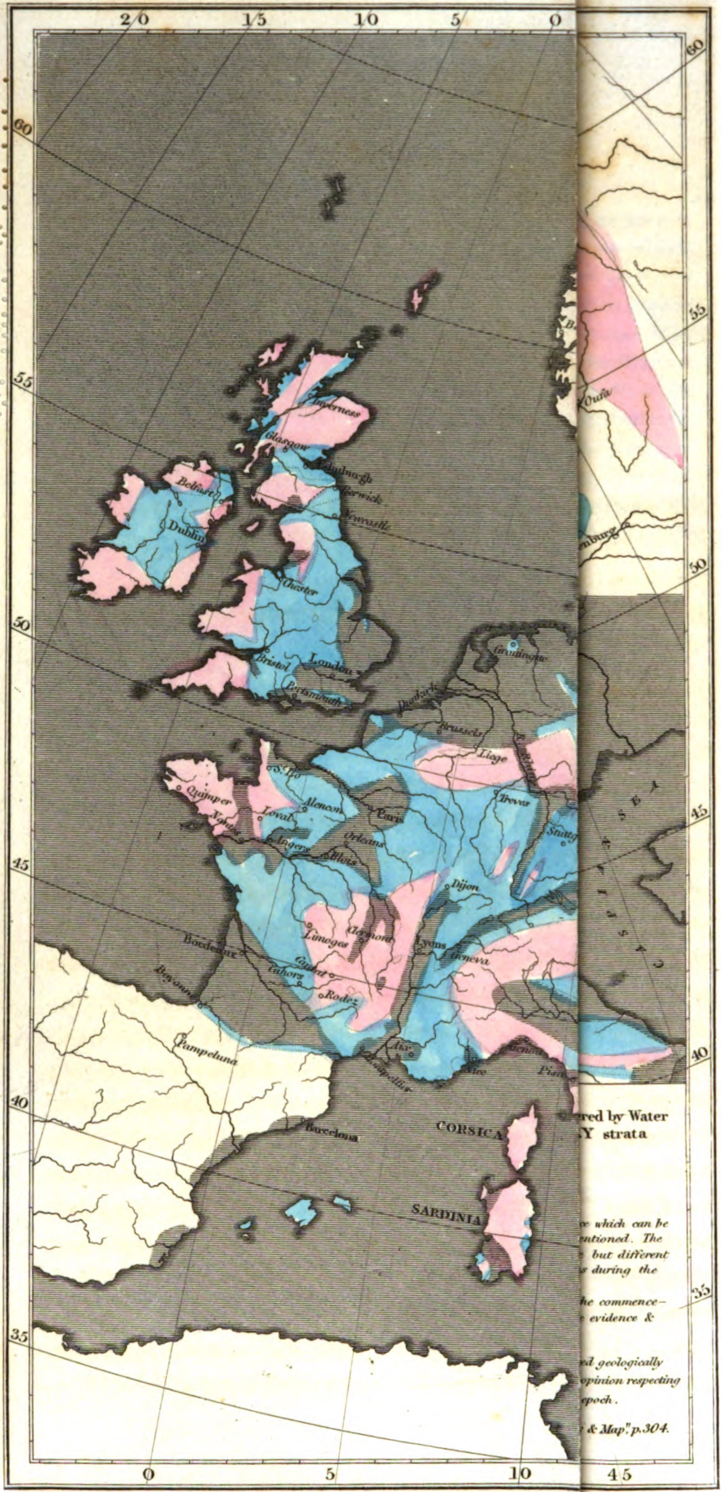
and forty years, some hundred thousand square miles of territory have been upheaved to the height of several feet, and that an area of equal, if not greater extent, has been depressed.

Now, they who contend, that formerly more movement was accomplished by earthquakes in the space of one hundred and forty years, must first explain the measure of time referred to, for it is obvious that they cannot in geology avail themselves of the annual revolution of our planet round the sun. Suppose they assume that the power of volcanos to emit lava, and of running water to transport sediment from one part of the globe to the other, has remained uniform from the earliest periods, they might then attempt to compare the effects of subterranean movements in ancient and modern times by reference to one common standard, and to show that, while a certain number of lava currents were produced, or so many cubic yards of sediment accumulated, the elevation and depression of the earth's crust were once much greater than they are now. Or, if they should declare that the progressive rate of change of species in the animal and vegetable kingdoms had always been uniform, they might then endeavour to disparage the degree of energy now exerted by earthquakes, by showing that, in relation to the mutations of assemblages of organic species, earthquakes had become comparatively feeble.

But our present scanty acquaintance, both with the animate and inanimate world, can by no means warrant such generalizations; nor have they who contend for the gradual decline of the activity of natural agents, attempted to support such a line of argument. That it would be most premature, in the present state of natural history, to reason on the comparative rate of fluctuation in the species of organic beings in ancient and modern times, will be more fully demonstrated when we proceed, in the next division of our subject, to consider the intimate connexion between geology, and the study of the present condition of the animal and vegetable kingdoms.

To conclude: it appears, from the views above explained,

respecting the agency of subterranean movements, that the constant repair of the dry land, and the subserviency of our planet to the support of terrestrial as well as aquatic species, are secured by the elevating and depressing power of earthquakes. This cause, so often the source of death and terror to the inhabitants of the globe, which visits, in succession, every zone, and fills the earth with monuments of ruin and disorder, is, nevertheless, a conservative principle in the highest degree, and, above all others, essential to the stability of the system.



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CHAPTER I.

Changes of the Organic World now in progress—Division of the subject—Examination of the question, Whether Species have a real existence in Nature?—Importance of this question in Geology—Sketch of Lamarck's arguments in favour of the Transmutation of Species, and his conjectures respecting the Origin of existing Animals and Plants—His Theory of the transformation of the Orang Outang into the Human Species.

CHANGES OF THE ORGANIC WORLD NOW IN PROGRESS.

Division of the Subject.—In our first volume we treated of the changes which have taken place in the inorganic world within the historical era, and we must next turn our attention to those now in progress in the animate creation. In examining this class of phenomena, we shall treat first of the vicissitudes to which *species* are subject, and afterwards consider the influence of the powers of vitality in modifying the surface of the earth and the material constituents of its crust.

The first of these divisions will lead us, among other topics, to inquire, first, whether species have a real and permanent existence in nature; or whether they are capable, as some naturalists pretend, of being indefinitely modified in the course of a long series of generations? Secondly, whether, if species have a real existence, the individuals composing them have been derived originally from many similar stocks, or each from one only, the descendants of which have spread themselves gradually from a particular point over the habitable lands and waters? Thirdly, how far the duration of each species of animal and plant is limited by its dependance on certain fluc-

tuating and temporary conditions in the state of the animate and inanimate world? Fourthly, whether there be proofs of the successive extermination of species in the ordinary course of nature, and whether there be any reason for conjecturing that new animals and plants are created from time to time, to supply their place?

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE.

Importance of this question in Geology.—Before we can advance a step in our proposed inquiry, we must be able to define precisely the meaning which we attach to the term species. This is even more necessary in geology than in the ordinary studies of the naturalist; for they who deny that such a thing as a species exists, concede nevertheless that a botanist or zoologist may reason as if the specific character were constant, because they confine their observations to a brief period of time. Just as the geographer, in constructing his maps from century to century, may proceed as if the apparent places of the fixed stars remained absolutely the same, and as if no alteration was brought about by the precession of the equinoxes, so it is said in the organic world, the stability of a species may be taken as absolute, if we do not extend our views beyond the narrow period of human history; but let a sufficient number of centuries elapse, to allow of important revolutions in climate, physical geography, and other circumstances, and the characters, say they, of the descendants of common parents may deviate indefinitely from their original type.

Now, if these doctrines be tenable, we are at once presented with a principle of incessant change in the organic world, and no degree of dissimilarity in the plants and animals which may formerly have existed, and are found fossil, would entitle us to conclude that they may not have been the prototypes and progenitors of the species now living. Accordingly M. Geoffroy St. Hilaire has declared his opinion, that there has been an uninterrupted succession in the animal kingdom effected by means of generation, from the earliest ages of the world

up to the present day; and that the ancient animals whose remains have been preserved in the strata, however different, may nevertheless have been the ancestors of those now in being. Although this notion is not generally received, we feel that we are not warranted in assuming the contrary, without fully explaining the data and reasoning by which we conceive it may be refuted.

We shall begin by stating as concisely as possible all the facts and ingenious arguments by which the theory has been supported, and for this purpose we cannot do better than offer the reader a rapid sketch of Lamarck's statement of the proofs which he regards as confirmatory of the doctrine, and which he has derived partly from the works of his predecessors, and in part from original investigations.

We shall consider his proofs and inferences in the order in which thy appear to have influenced his mind, and point out some of the results to which he was led while boldly following out his principles to their legitimate consequences.

Lamarck's arguments in favour of the Transmutation of Species—The name of species, observes Lamarck, has been usually applied to 'every collection of similar individuals, produced by other individuals like themselves *.' This definition, he admits, is correct, because every living individual bears a very close resemblance to those from which it springs. But this is not all which is usually implied by the term species, for the majority of naturalists agree with Linnæus in supposing that all the individuals propagated from one stock have certain distinguishing characters in common which will never vary, and which have remained the same since the creation of each species.

In order to shake this opinion, Lamarck enters upon the following line of argument. The more we advance in the knowledge of the different organized bodies which cover the surface of the globe, the more our embarrassment increases, to determine what ought to be regarded as a species, and still

* Phil. Zool. tom. i. p. 54.

more how to limit and distinguish genera. In proportion as our collections are enriched, we see almost every void filled up, and all our lines of separation effaced; we are reduced to arbitrary determinations, and are sometimes fain to seize upon the slight differences of mere varieties, in order to form characters for what we choose to call a species, and sometimes we are induced to pronounce individuals but slightly differing, and which others regard as true species, to be varieties.

The greater the abundance of natural objects assembled together, the more do we discover proofs that everything passes by insensible shades into something else: that even the more remarkable differences are evanescent, and that nature has, for the most part, left us nothing at our disposal for establishing distinctions, save trifling and, in some respects, puerile particularities.

We find that many genera amongst animals and plants are of such an extent, in consequence of the number of species referred to them, that the study and determination of these last has become almost impracticable. When the species are arranged in a series, and placed near to each other, with due regard to their natural affinities, they each differ in so minute a degree from those next adjoining, that they almost melt into each other, and are in a manner confounded together. If we see isolated species, we may presume the absence of some more closely connected, and which have not yet been discovered. Already are there genera, and even entire orders,—nay whole classes, which present an approximation to the state of things here indicated.

If, when species have been thus placed in a regular series, we select one, and then, making a leap over several intermediate ones, we take a second, at some distance from the first, these two will, on comparison, be seen to be very dissimilar; and it is in this manner that every naturalist begins to study the objects which are at his own door. He then finds it an easy task to establish generic and specific distinctions; and it is only when his experience is enlarged, and when he has made

himself master of the intermediate links, that his difficulties and ambiguities begin. But while we are thus compelled to resort to trifling and minute characters in our attempt to separate species, we find a striking disparity between individuals which we know to have descended from a common stock, and these newly-acquired peculiarities are regularly transmitted from one generation to another, constituting what are called *races*.

From a great number of facts, continues the author, we learn that in proportion as the individuals of one of our species change their situation, climate and manner of living, they change also, by little and little, the consistence and proportions of their parts, their form, their faculties, and even their organization, in such a manner that everything in them comes at last to participate in the mutations to which they have been exposed. Even in the same climate a great difference of situation and exposure causes individuals to vary ; but if these individuals continue to live and to be reproduced under the same difference of circumstances, distinctions are brought about in them which become in some degree essential to their existence. In a word, at the end of many successive generations, these individuals, which originally belonged to another species, are transformed into a new and distinct species *.

Thus, for example, if the seeds of a grass, or any other plant which grows naturally in a moist meadow, be accidentally transported, first to the slope of some neighbouring hill, where the soil, although at a greater elevation, is damp enough to allow the plant to live ; and if, after having lived there, and having been several times regenerated, it reaches by degrees the drier and almost arid soil of a mountain declivity, it will then, if it succeeds in growing and perpetuates itself for a series of generations, be so changed that botanists who meet with it will regard it as a particular species †. The unfavourable climate in this case, deficiency of nourishment, exposure to the winds, and other causes, give

* Phil. Zool. tom. i. p. 62. † Ibid.

rise to a stunted and dwarfish race, with some organ more developed than others, and having proportions often quite peculiar.

What nature brings about in a great lapse of time, we occasion suddenly by changing the circumstances in which a species has been accustomed to live. All are aware that vegetables taken from their birth-place and cultivated in gardens, undergo changes which render them no longer recognizable as the same plants. Many which were naturally hairy become smooth or nearly so; a great number of such as were creepers and trailed along the ground, rear their stalks and grow erect. Others lose their thorns or asperities; others again, from the ligneous state which their stem possessed in hot climates, where they were indigenous, pass to the herbaceous, and, among them, some which were perennials become mere annuals. So well do botanists know the effects of such changes of circumstances, that they are averse to describe species from garden specimens, unless they are sure that they have been cultivated for a very short period.

'Is not the cultivated wheat,' (*Triticum sativum*) asks Lamarck, 'a vegetable brought by man into the state in which 'we now see it? Let any one tell me in what country a similar 'plant grows wild, unless where it has escaped from cultivated 'fields? Where do we find in nature our cabbages, lettuces, 'and other culinary vegetables, in the state in which they 'appear in our gardens? Is it not the same in regard to 'a great quantity of animals which domesticity has changed 'or considerably modified*?' Our domestic fowls and pigeons are unlike any wild birds. Our domestic ducks and geese have lost the faculty of raising themselves into the higher regions of the air, and crossing extensive countries in their flight, like the wild ducks and wild geese from which they were originally derived. A bird which we breed in a cage cannot, when restored to liberty, fly like others of the same species which have been always free. This small alteration of

* Phil. Zool. tom. i. p. 227.

circumstances, however, has only diminished the power of flight, without modifying the form of any part of the wings. But when individuals of the same race are retained in captivity during a considerable length of time, the form even of their parts is gradually made to differ, especially if climate, nourishment, and other circumstances, be also altered.

The numerous races of dogs which we have produced by domesticity are nowhere to be found in a wild state. In nature we should seek in vain for mastiffs, harriers, spaniels, greyhounds, and other races, between which the differences are sometimes so great, that they would be readily admitted as specific between wild animals; 'yet all these have sprung 'originally from a single race, at first approaching very near 'to a wolf, if, indeed, the wolf be not the true type which at 'some period or other was domesticated by man.'

Although important changes in the nature of the places which they inhabit modify the organization of animals as well as vegetables, yet the former, says Lamarck, require more time to complete a considerable degree of transmutation, and, consequently, we are less sensible of such occurrences. Next to a diversity of the medium in which animals or plants may live, the circumstances which have most influence in modifying their organs are differences in exposure, climate, the nature of the soil, and other local particulars. These *circumstances* are as varied as are the characters of species, and, like them, pass by insensible shades into each other, there being every intermediate gradation between the opposite extremes. But each locality remains for a very long time the same, and is altered so slowly that we can only become conscious of the reality of the change, by consulting geological monuments, by which we learn that the order of things which now reigns in each place has not always prevailed, and by inference anticipate that it will not always continue the same *.

Every considerable alteration in the local circumstances in

* Phil. Zool., tom. i. p. 232.

which each race of animals exists, causes a change in their wants, and these new wants excite them to new actions and habits. These actions require the more frequent employment of some parts before but slightly exercised, and then greater development follows as a consequence of their more frequent use. Other organs no longer in use are impoverished and diminished in size, nay, are sometimes entirely annihilated, while in their place new parts are insensibly produced for the discharge of new functions *.

We must here interrupt the author's argument, by observing that no positive fact is cited to exemplify the substitution of some *entirely new* sense, faculty, or organ, in the room of some other suppressed as useless. All the instances adduced go only to prove that the dimensions and strength of members and the perfection of certain attributes may, in a long succession of generations, be lessened and enfeebled by disuse; or, on the contrary, be matured and augmented by active exertion, just as we know that the power of scent is feeble in the greyhound, while its swiftness of pace and its acuteness of sight are remarkable—that the harrier and stag-hound, on the contrary, are comparatively slow in their movements, but excel in the sense of smelling.

We point out to the reader this important chasm in the chain of the evidence, because he might otherwise imagine that we had merely omitted the illustrations for the sake of brevity, but the plain truth is, that there were no examples to be found; and when Lamarck talks 'of the efforts of internal sentiment,' 'the influence of subtle fluids,' and the 'acts of organization,' as causes whereby animals and plants may acquire *new organs*, he gives us names for things, and with a disregard to the strict rules of induction, resorts to fictions, as ideal as the 'plastic virtue,' and other phantoms of the middle ages.

It is evident, that if some well authenticated facts could

* Phil. Zool., tom. i. p. 234.

have been adduced to establish one complete step in the process of transformation, such as the appearance, in individuals descending from a common stock, of a sense or organ entirely new, and a complete disappearance of some other enjoyed by their progenitors, that time alone might then be supposed sufficient to bring about any amount of metamorphosis. The gratuitous assumption, therefore, of a point so vital to the theory of transmutation, was unpardonable on the part of its advocate.

But to proceed with the system; it being assumed as an undoubted fact, that a change of external circumstances may cause one organ to become entirely obsolete, and a new one to be developed, such as never before belonged to the species, the following proposition is announced, which, however staggering and absurd it may seem, is logically deduced from the assumed premises. 'It is not the organs, or, in other words, the nature and form of the parts of the body of an animal which have given rise to its habits, and its particular faculties, but, on the contrary, its habits, its manner of living, and those of its progenitors have in the course of time determined the form of its body, the number and condition of its organs, in short, the faculties which it enjoys. Thus otters, beavers, water-fowl, turtles, and frogs, were not made web-footed in order that they might swim; but their wants having attracted them to the water in search of prey, they stretched out the toes of their feet to strike the water and move rapidly along its surface. By the repeated stretching of their toes, the skin which united them at the base, acquired a habit of extension, until in the course of time the broad membranes which now connect their extremities were formed.

In like manner the antelope and the gazelle were not endowed with light agile forms, in order that they might escape by flight from carnivorous animals; but having been exposed to the danger of being devoured by lions, tigers, and other beasts of prey, they were compelled to exert themselves in running with great celerity, a habit which, in the course of

many generations, gave rise to the peculiar slenderness of their legs, and the agility and elegance of their forms.

The cameleopard was not gifted with a long flexible neck because it was destined to live in the interior of Africa, where the soil was arid and devoid of herbage, but being reduced by the nature of that country to support itself on the foliage of lofty trees, it contracted a habit of stretching itself up to reach the high boughs, until its fore-legs became longer than the hinder, and its neck so elongated, that it could raise its head to the height of twenty feet above the ground.'

Another line of argument is then entered upon, in further corroboration of the instability of species. In order it is said that individuals should perpetuate themselves unaltered by generation, those belonging to one species ought never to ally themselves to those of another: but such sexual unions do take place, both among plants and animals; and although the offspring of such irregular connexions are usually sterile, yet such is not always the case. Hybrids have sometimes proved prolific where the disparity between the species was not too great; and by this means alone, says Lamarck, varieties may gradually be created by near alliances, which would become races, and in the course of time would constitute what we term species *.

But if the soundness of all these arguments and inferences be admitted, we are next to inquire, what were the original types of form, organization, and instinct, from which the diversities of character, as now exhibited by animals and plants, have been derived? We know that individuals which are mere varieties of the same species, would, if their pedigree could be traced back far enough, terminate in a single stock; so according to the train of reasoning before described, the species of a genus, and even the genera of a great family, must have had a common point of departure. What then was the single stem from which so many varieties of form have ramified? Were there many of these, or are we to refer the origin

* Phil. Zool. p. 64.

of the whole animate creation, as the Egyptian priests did that of the universe, to a single egg?

In the absence of any positive data for framing a theory on so obscure a subject, the following considerations were deemed of importance to guide conjecture.

In the first place, if we examine the whole series of known animals, from one extremity to the other, when they are arranged in the order of their natural relations, we find that we may pass progressively, or at least with very few interruptions, from beings of more simple to those of a more compound structure; and in proportion as the complexity of their organization increases, the number and dignity of their faculties increase also. Among plants a similar approximation to a graduated scale of being is apparent. Secondly, it appears from geological observations, that plants and animals of more simple organization existed on the globe before the appearance of those of more compound structure, and the latter were successively formed at later periods: each new race being more fully developed than the most perfect of the preceding era.

Of the truth of the last-mentioned geological theory, Lamarck seems to have been fully persuaded; and he also shows that he was deeply impressed with a belief prevalent amongst the older naturalists, that the primeval ocean invested the whole planet long after it became the habitation of living beings, and thus he was inclined to assert the priority of the types of marine animals to those of the terrestrial, and to fancy, for example, that the testacea of the ocean existed first, until some of them, by gradual evolution, were *improved* into those inhabiting the land.

These speculative views had already been, in a great degree, anticipated by Demaillet in his Telliamed, and by several modern writers, so that the tables were completely turned on the philosophers of antiquity, with whom it was a received maxim, that created things were always most perfect when they came first from the hands of their Maker, and that there was a

tendency to progressive deterioration in sublunary things when left to themselves—

——————— omnia fatis
In pejus ruere, ac retrò sublapsa referri.

So deeply was the faith of the ancient schools of philosophy imbued with this doctrine, that to check this universal proneness to degeneracy, nothing less than the re-intervention of the Deity was thought adequate; and it was held, that thereby the order, excellence, and pristine energy of the moral and physical world had been repeatedly restored.

But when the possibility of the indefinite modification of individuals descending from common parents was once assumed, as also the geological inference respecting the progressive development of organic life, it was natural that the ancient dogma should be rejected, or rather reversed; and that the most simple and imperfect forms and faculties should be conceived to have been the originals whence all others were developed. Accordingly, in conformity to these views, inert matter was supposed to have been first endowed with life; until, in the course of ages, sensation was superadded to mere vitality: sight, hearing, and the other senses, were afterwards acquired; and then instinct and the mental faculties, until, finally, by virtue of the tendency of things to *progressive improvement*, the irrational was developed into the rational.

The reader, however, will immediately perceive, that if all the higher order of plants and animals were thus supposed to be comparatively modern, and to have been derived in a long series of generations from those of more simple conformation, some further hypothesis became indispensable, in order to explain why, after an indefinite lapse of ages, there were still so many beings of the simplest structure. Why have the majority of existing creatures remained stationary throughout this long succession of epochs, while others have made such prodigious advances? Why are there such multitudes of infusoria and polyps, or of confervæ and other cryptogamic plants? Why, moreover, has the process of development

acted with such unequal and irregular force on those classes of beings which have been greatly perfected, so that there are wide chasms in the series; gaps so enormous, that Lamarck fairly admits we can never expect to fill them up by future discoveries?

The following hypothesis was provided to meet these objections. Nature, we are told, is not an intelligence, nor the Deity, but a delegated power—a mere instrument—a piece of mechanism acting by necessity—an order of things constituted by the Supreme Being, and subject to laws which are the expressions of his will. This nature is *obliged* to proceed gradually in all her operations; she cannot produce animals and plants of all classes at once, but must always begin by the formation of the most simple kinds; and out of them elaborate the more compound, adding to them successively, different systems of organs, and multiplying more and more their number and energy.

This Nature is daily engaged in the formation of the elementary rudiments of animal and vegetable existence, which correspond to what the ancients termed *spontaneous generations*. She is always beginning anew, day by day, the work of creation, by forming monads, or 'rough draughts' (ébauches), which are the only living things she gives birth to *directly*.

There are distinct primary rudiments of plants and animals, and *probably* of each of the great divisions of the animal and vegetable kingdoms *. These are gradually developed into the higher and more perfect classes by the slow, but unceasing agency of two influential principles: first, *the tendency to progressive advancement* in organization, accompanied by greater dignity in instinct, intelligence, &c.; secondly, *the force of external circumstances*, or of variations in the physical condition of the earth, or the mutual relations of plants and animals. For as species spread themselves gradually over the globe, they are exposed from time to time to variations in

* Animaux sans Vert., tom. i. p. 56, Introduction.

climate, and to changes in the quantity and quality of their food; they meet with new plants and animals which assist or retard their development, by supplying them with nutriment, or destroying their foes. The nature also of each locality is in itself fluctuating, so that even if the relation of other animals and plants were invariable, the habits and organization of species would be modified by the influence of local revolutions.

Now, if the first of these principles, *the tendency to progressive development*, were left to exert itself with perfect freedom, it would give rise, says Lamarck, in the course of ages, to a graduated scale of being, where the most insensible transition might be traced from the simplest to the most compound structure, from the humblest to the most exalted degree of intelligence. But in consequence of the perpetual interference of the *external causes* before mentioned, this regular order is greatly interfered with, and an approximation only to such a state of things is exhibited by the animate creation, the progress of some races being retarded by unfavourable, and that of others accelerated by favourable, combinations of circumstances. Hence, all kinds of anomalies interrupt the continuity of the plan, and chasms, into which whole genera or families might be inserted, are seen to separate the nearest existing portions of the series.

Lamarck's theory of the transformation of the Orang-Outang into the human species.—Such is the machinery of the Lamarckian system; but our readers will hardly, perhaps, be able to form a perfect conception of so complicated a piece of mechanism, unless we exhibit it in motion, and show in what manner it can work out, under the author's guidance, all the extraordinary effects which we behold in the present state of the animate creation. We have only space for exhibiting a small part of the entire process by which a complete metamorphosis is achieved, and shall, therefore, omit the mode whereby, after a countless succession of generations, a small gelatinous body is transformed into an oak or an ape. We pass

on at once to the last grand step in the progressive scheme, whereby the orang-outang, having been already evolved out of a monad, is made slowly to attain the attributes and dignity of man.

One of the races of quadrumanous animals which had reached the highest state of perfection, lost, by constraint of circumstances, (concerning the exact nature of which tradition is unfortunately silent,) the habit of climbing trees, and of hanging on by grasping the boughs with their feet as with hands. The individuals of this race being obliged for a long series of generations to use their feet exclusively for walking, and ceasing to employ their hands as feet, were transformed into bimanous animals, and what before were thumbs became mere toes, no separation being required when their feet were used solely for walking. Having acquired a habit of holding themselves upright, their legs and feet assumed insensibly a conformation fitted to support them in an erect attitude, till at last these animals could no longer go on all fours without much inconvenience.

The Angola orang, *Simia troglodytes*, Linn., is the most perfect of animals, much more so than the Indian orang, *Simia Satyrus*, which has been called the orang-outang, although *both* are *very inferior* to man in corporeal powers and intelligence. These animals frequently hold themselves upright, but their organization has *not yet* been sufficiently modified to sustain them habitually in this attitude, so that the standing posture is very uneasy to them. When the Indian orang is compelled to take flight from pressing danger, he immediately falls down upon all fours, showing clearly that this was the original position of the animal. Even in man, whose organization, in the course of a long series of generations, has advanced so much farther, the upright posture is fatiguing and can only be supported for a limited time, and by aid of the contraction, of many muscles. If the vertebral column formed the axis of the human body, and supported the head and all the other parts in equilibrium, then might the

upright position be a state of repose: but as the human head does not articulate in the centre of gravity; as the chest belly, and other parts, press almost entirely forward with their whole weight, and as the vertebral column reposes upon an oblique base, a watchful activity is required to prevent the body from falling. Children which have large heads and prominent bellies can hardly walk at the end even of two years, and their frequent tumbles indicate the natural tendency in man to resume the quadrupedal state.

Now, when so much progress had been made by the quadrumanous animals before mentioned, that they could hold themselves habitually in an erect attitude, and were accustomed to a wide range of vision, and ceased to use their jaws for fighting, and tearing, or for clipping herbs for food, their snout became gradually shorter, their incisor teeth became vertical, and the facial angle grew more open.

Among other ideas which the natural *tendency to perfection* engendered, the desire of ruling suggested itself, and this race succeeded at length in getting the better of the other animals, and made themselves masters of all those spots on the surface of the globe which best suited them. They drove out the animals which approached nearest to them in organization and intelligence, and which were in a condition to dispute with them the good things of this world, forcing them to take refuge in deserts, woods and wildernesses, where their multiplication was checked, and the progressive development of their faculties retarded, while in the mean time the dominant race spread itself in every direction, and lived in large companies where new wants were successively created, exciting them to industry, and gradually perfecting their means and faculties.

In the supremacy and increased intelligence acquired by the ruling race, we see an illustration of the natural tendency of the organic world to grow more perfect, and in their influence in repressing the advance of others, an example of one of those disturbing causes before enumerated, that *force of external cir-*

cumstances, which causes such wide chasms in the regular series of animated beings.

When the individuals of the dominant race became very numerous, their ideas greatly increased in number, and they felt the necessity of communicating them to each other, and of augmenting and varying the signs proper for the communication of ideas. Meanwhile the inferior quadrumanous animals, although most of them were gregarious, acquired no new ideas, being persecuted and restless in the deserts, and obliged to fly and conceal themselves, so that they conceived no new wants. Such ideas as they already had remained unaltered, and they could dispense with the communication of the greater part of these. To make themselves, therefore, understood by their fellows, required merely a few movements of the body or limbs—whistling, and the uttering of certain cries varied by the inflexions of the voice.

On the contrary, the individuals of the ascendant race, animated with a desire of interchanging their ideas, which became more and more numerous, were prompted to multiply the means of communication, and were no longer satisfied with mere pantomimic signs, nor even with all the possible inflexions of the voice, but made continual efforts to acquire the power of uttering articulate sounds, employing a few at first, but afterwards varying and perfecting them according to the increase of their wants. The habitual exercise of their throat, tongue and lips, insensibly modified the conformation of these organs, until they became fitted for the faculty of speech *.

In effecting this mighty change, 'the exigencies of the individuals were the sole agents, they gave rise to efforts, and the organs proper for articulating sounds were developed by their habitual employment.' Hence, in this peculiar race, the origin of the admirable faculty of speech; hence also the diversity of languages, since the distance of places where the individuals composing the race established themselves, soon favoured the corruption of conventional signs †.

* Lamarck's Phil. Zool., tom. i. p. 356. † Ibid. p. 357.

CHAPTER II.

Recapitulation of the arguments in favour of the theory of transmutation of species—Their insufficiency—The difficulty of discriminating species mainly attributable to a defective knowledge of their history—Some mere varieties possibly more distinct than certain individuals of distinct species—Variability in a species consistent with a belief that the limits of deviation are fixed—No facts of transmutation authenticated—Varieties of the Dog—The Dog and Wolf distinct species—Mummies of various animals from Egypt identical in character with living individuals—Seeds and plants from the Egyptian tombs—Modifications produced in plants by agriculture and gardening.

RECAPITULATION OF THE ARGUMENTS IN FAVOUR OF THE THEORY OF THE TRANSMUTATION OF SPECIES.

The theory of the transmutation of species, considered in the last chapter, has met with some degree of favour from many naturalists, from their desire to dispense, as far as possible, with the repeated intervention of a First Cause, as often as geological monuments attest the successive appearance of new races of animals and plants, and the extinction of those pre-existing. But, independently of a predisposition to account, if possible, for a series of changes in the organic world, by the regular action of secondary causes, we have seen that many perplexing difficulties present themselves to one who attempts to establish the nature and the reality of the specific character. And if once there appears ground of reasonable doubt, in regard to the constancy of species, the amount of transformation which they are capable of undergoing may seem to resolve itself into a mere question of the quantity of time assigned to the past duration of animate existence.

Before we enter upon our reasons for rejecting Lamarck's hypothesis, we shall recapitulate, in a few words, the phenomena, and the whole train of thought, by which we conceive it to have been suggested, and which have gained for this and

analogous theories, both in ancient and modern times, a considerable number of votaries.

In the first place, the various groups into which plants and animals may be thrown, seem almost invariably, to a beginner, to be so natural, that he is usually convinced at first, as was Linnæus to the last, 'that genera are as much founded in nature as the species which compose them *.' When by examining the numerous intermediate gradations, the student finds all lines of demarcation to be in most instances obliterated, even where they at first appeared most distinct, he grows more and more sceptical as to the real existence of genera, and finally regards them as mere arbitrary and artificial signs, invented like those which serve to distinguish the heavenly constellations for the convenience of classification, and having as little pretensions to reality.

Doubts are then engendered in his mind as to whether species may not also be equally unreal. The student is probably first struck with the phenomenon, that some individuals are made to deviate widely from the ordinary type by the force of peculiar circumstances, and with the still more extraordinary fact, that the newly-acquired peculiarities are faithfully transmitted to the offspring. How far, he asks, may such variations extend in the course of indefinite periods of time, and during great vicissitudes in the physical condition of the globe? His growing incertitude is at first checked by the reflection that nature has forbidden the intermixture of the descendants of distinct original stocks, or has, at least, entailed sterility on their offspring, thereby preventing their being confounded together, and pointing out that a multitude of distinct types must have been created in the beginning, and must have remained pure and uncorrupted to this day.

Relying on this general law, he endeavours to solve each difficult problem by direct experiment, until he is again astounded by the phenomenon of a prolific hybrid, and still more by an example of a hybrid perpetuating itself through

* Sir J. Smith's Introduction to Botany.

out several generations in the vegetable world. He then feels himself reduced to the dilemma of choosing between two alternatives, either to reject the test, or to declare that the two species, from the union of which the fruitful progeny has sprung, were mere varieties. If he prefer the latter, he is compelled to question the reality of the distinctness of all other supposed species which differ no more than the parents of such prolific hybrids; for although he may not be enabled immediately to procure, in all such instances, a fruitful offspring, yet experiments show, that after repeated failures the union of two recognized species may at last, under very favourable circumstances, give birth to a fertile progeny. Such circumstances, therefore, the naturalist may conceive to have occurred again and again, in the course of a great lapse of ages.

His first opinions are now fairly unsettled, and every stay at which he has caught has given way one after another; he is in danger of falling into any new and visionary doctrine which may be presented to him; for he now regards every part of the animate creation as void of stability, and in a state of continual flux. In this mood he encounters the Geologist, who relates to him how there have been endless vicissitudes in the shape and structure of organic beings in former ages—how the approach to the present system of things has been gradual—that there has been a progressive development of organization subservient to the purposes of life, from the most simple to the most complex state—that the appearance of man is the last phenomenon in a long succession of events—and finally, that a series of physical revolutions can be traced in the inorganic world, coeval and coextensive with those of organic nature.

These views seem immediately to confirm all his preconceived doubts as to the stability of the specific character, and he thinks he can discern an inseparable connexion between a series of changes in the inanimate world, and the capability of species to be indefinitely modified by the influence of external circumstances. Henceforth his speculations know no definite

bounds; he gives the rein to conjecture, and fancies that the outward form, internal structure, instinctive faculties, nay, that reason itself may have been gradually developed from some of the simplest states of existence—that all animals, that man himself, and the irrational beings, may have had one common origin; that all may be parts of one continuous and progressive scheme of development from the most imperfect to the more complex; in fine, he renounces his belief in the high genealogy of his species, and looks forward, as if in compensation, to the future perfectibility of man in his physical, intellectual, and moral attributes.

Let us now proceed to consider what is defective in evidence, and what fallacious in reasoning, in the grounds of these strange conclusions. Blumenbach judiciously observes, 'that no general rule can be laid down for determining the distinctness of species, as there is no particular class of characters which can serve as a criterion. In each case we must be guided by *analogy* and *probability*.' The multitude, in fact, and complexity of the proofs to be weighed, is so great, that we can only hope to obtain presumptive evidence, and we must, therefore, be the more careful to derive our general views as much as possible from those observations where the chances of deception are least. We must be on our guard not to tread in the footsteps of the naturalists of the middle ages, who believed the doctrine of spontaneous generation to be applicable to all those parts of the animal and vegetable kingdoms which they least understood, in direct contradiction to the analogy of all the parts best known to them; and who, when at length they found that insects and cryptogamous plants were also propagated from eggs and seeds, still persisted in retaining their old prejudices respecting the infusory animalcules and other minute beings, the generation of which had not then been demonstrated by the microscope to be governed by the same laws.

Lamarck has indeed attempted to raise an argument, in favour of his system, out of the very confusion which has

arisen in the study of some orders of animals and plants, in consequence of the slight shades of difference which separate the new species discovered within the last half century. That the embarrassment of those who attempt to classify and distinguish the new acquisitions poured in such multitudes into our museums should increase with the augmentation of their number is quite natural; for to obviate this it is not enough that our powers of discrimination should keep pace with the increase of the objects, but we ought to possess greater opportunities of studying each animal and plant in all stages of its growth, and to know profoundly their history, their habits and physiological characters, throughout several generations. For, in proportion as the series of known animals grows more complete, none can doubt that there is a nearer approximation to a graduated scale of being; and thus the most closely allied species will possess a greater number of characters in common.

Cause of the difficulty of discriminating species.—But, in point of fact, our new acquisitions consist, more and more as we advance, of specimens brought from foreign and often very distant and barbarous countries. A large proportion have never even been seen alive by scientific inquirers. Instead of having specimens of the young, the adult, and the aged individuals of each sex, and possessing means of investigating the anatomical structure, the peculiar habits and instincts of each, what is usually the state of our information? A single specimen, perhaps, of a dried plant, or a stuffed bird or quadruped; a shell without the soft parts of the animal; an insect in one stage of its numerous transformations; these are the scanty and imperfect data, which the naturalist possesses. Such information may enable us to separate species which stand at a considerable distance from each other; but we have no right to expect anything but difficulty and ambiguity, if we attempt, from such imperfect opportunities, to obtain distinctive marks for defining the characters of species, which are closely related,

If Lamarck could introduce so much certainty and precision into the classification of several thousand species of recent and fossil shells, notwithstanding the extreme remoteness of the organization of these animals from the type of those vertebrated species which are best known, and in the absence of so many of the living inhabitants of shells, we are led to form an exalted conception of the degree of exactness to which specific distinctions are capable of being carried, rather than to call in question their reality.

When our data are so defective, the most acute naturalist must expect to be sometimes at fault, and, like the novice, to overlook essential points of difference, passing unconsciously from one species to another, until, like one who is borne along in a current, he is astonished, on looking back, at observing that he has reached a point so remote from that whence he set out.

It is by no means improbable that when the series of species of certain genera is very full, they may be found to differ less widely from each other, than do the mere varieties or races of certain species. If such a fact could be established, it would by no means overthrow our confidence in the reality of species, although it would certainly diminish the chance of our obtaining certainty in our results.

Some mere varieties possibly more distinct than certain individuals of distinct species.—It is almost necessary, indeed, to suppose that varieties will differ in some cases, more decidedly than some species, if we admit that there is a graduated scale of being, and assume that the following laws prevail in the economy of the animate creation:—first, that the organization of individuals is capable of being modified to a limited extent by the force of external causes; secondly, that these modifications are, to a certain extent, transmissible to their offspring; thirdly, that there are fixed limits beyond which the descendants from common parents can never deviate from a certain type; fourthly, that each species springs from one original stock, and can never be permanently confounded by

intermixing with the progeny of any other stock; fifthly, that each species shall endure for a considerable period of time. Now if we assume, for the present, these rules hypothetically, let us see what consequences may naturally be expected to result.

We must suppose, that when the Author of Nature creates an animal or plant, all the possible circumstances in which its descendants are destined to live are foreseen, and that an organization is conferred upon it which will enable the species to perpetuate itself and survive under all the varying circumstances to which it must be inevitably exposed. Now the range of variation of circumstances will differ essentially in almost every case. Let us take for example any one of the most influential conditions of existence, such as temperature. In some extensive districts near the equator, the thermometer might never vary throughout several thousand centuries for more than 20° Fahrenheit; so that if a plant or animal be provided with an organization fitting it to endure such a range, it may continue on the globe for that immense period, although every individual might be liable at once to be cut off by the least possible excess of heat or cold beyond the determinate quantity. But if a species be placed in one of the temperate zones, and have a constitution conferred on it capable of supporting a similar range of temperature only, it will inevitably perish before a single year has passed away.

The same remark might be applied to any other condition, as food for example: it may be foreseen that the supply will be regular throughout indefinite periods in one part of the world, and in another very precarious and fluctuating both in kind and quantity. Different qualifications may be required for enabling species to live for a considerable time under circumstances so changeable. If, then, temperature and food be among those external causes, which according to certain laws of animal and vegetable physiology modify the organization, form, or faculties of individuals, we instantly perceive that the degrees of variability from a common

standard must differ widely in the two cases above supposed, since there is a necessity of accommodating a species in one case to a much greater latitude of circumstances than in the other.

If it be a law, for instance, that scanty sustenance should check those individuals in their growth which are enabled to accommodate themselves to privations of this kind, and that a parent, prevented in this manner from attaining the size proper to its species should produce a dwarfish offspring, a stunted race will arise, as is remarkably exemplified in some varieties of the horse and dog. The difference of stature in some races of dogs in comparison to others, is as one to five in linear dimensions, making a difference of a hundred-fold in volume *. Now there is good reason to believe that species in general are by no means susceptible of existing under a diversity of circumstances, which may give rise to such a disparity in size, and consequently, there will be a multitude of distinct species, of which no two adult individuals can ever depart so widely from a certain standard of dimensions as the mere varieties of certain other species,—the dog for instance. Now we have only to suppose that what is true of size, may also hold in regard to colour and many other attributes, and it will at once follow that the degree of possible discordance between varieties of the same species, may in certain cases exceed the utmost disparity which can arise between two individuals of many distinct species.

The same remarks may hold true in regard to instincts; for if it be foreseen that one species will have to encounter a great variety of foes, it may be necessary to arm it with great cunning and circumspection, or with courage or other qualities capable of developing themselves on certain occasions; such for example as those migratory instincts which are so remarkably exhibited at particular periods, after they have remained dormant for many generations. The history and habits of one variety of such a species may often differ more considerably from some other than those of many distinct species

* Cuvier, Disc. Prelim., p. 128, sixth edition.

which have no such latitude of accommodation to circumstances.

Extent of known variability in Species.—Lamarck has somewhat misstated the idea commonly entertained of a species, for it is not true that naturalists in general assume that the organization of an animal or plant remains absolutely constant, and that it can never vary in any of its parts. All must be aware that circumstances influence the habits, and that the habits may alter the state of the parts and organs *. But the difference of opinion relates to the extent to which these modifications of the habits and organs of a particular species may be carried.

Now let us first inquire what positive facts can be adduced in the history of known species, to establish a great and permanent amount of change in the form, structure, or instinct of individuals descending from some common stock. The best authenticated examples of the extent to which species can be made to vary, may be looked for in the history of domesticated animals and cultivated plants. It usually happens that those species, both of the animal and vegetable kingdom, which have the greatest pliability of organization, those which are most capable of accommodating themselves to a great variety of new circumstances, are most serviceable to man. These only can be carried by him into different climates, and can have their properties or instincts variously diversified by differences of nourishment and habits. If the resources of a species be so limited, and its habits and faculties be of such a confined and local character, that it can only flourish in a few particular spots, it can rarely be of great utility.

We may consider, therefore, that in perfecting the arts of domesticating animals and cultivating plants, mankind have first selected those species which have the most flexible frames and constitutions, and have then been engaged for ages in conducting a series of experiments, with much patience and at great cost, to ascertain what may be the greatest possible

* Phil. Zool., tom. i. p. 266.

deviation from a common type which can be elicited in these extreme cases.

Varieties of the Dog.—The modifications produced in the different races of dogs, exhibit the influence of man in the most striking point of view. These animals have been transported into every climate, and placed in every variety of circumstances; they have been made, as a modern naturalist observes, the servant, the companion, the guardian, and the intimate friend of man, and the power of a superior genius has had a wonderful influence, not only on their forms, but on their manners and intelligence *. Different races have undergone remarkable changes in the quantity and colour of their clothing: the dogs of Guinea are almost naked, while those of the Arctic circle are covered with a warm coat both of hair and wool, which enables them to bear the most intense cold without inconvenience. There are differences also of another kind no less remarkable, as in size, the length of their muzzles, and the convexity of their foreheads.

No facts of transmutation authenticated.—But if we look for some of those essential changes which would be required to lend even the semblance of a foundation for the theory of Lamarck, respecting the growth of new organs and the gradual obliteration of others, we find nothing of the kind. For in all these varieties of the dog, says Cuvier, the relation of the bones with each other remain essentially the same; the form of the teeth never changes in any perceptible degree, except that in some individuals, one additional false grinder occasionally appears, sometimes on the one side, and sometimes on the other †. The greatest departure from a common type, and it constitutes the maximum of variation as yet known in the animal kingdom, is exemplified in those races of dogs which have a supernumerary toe on the hind foot with the corresponding tarsal bones, a variety analogous to one presented by six-fingered families of the human race ‡.

* Dureau de la Malle, Ann. des Sci. Nat. tom. xxi. p. 63. Sept. 1830.

† Disc. Prel., p. 129, sixth edition. ‡ Ibid.

Lamarck has thrown out as a conjecture, that the wolf may have been the original of the dog, but he has adduced no data to bear out such an hypothesis. 'The wolf,' observes Dr. Prichard, 'and the dog differ, not only with respect to their habits and instincts, which in the brute creation are very uniform within the limits of one species; but some differences have also been pointed out in their internal organization, particularly in the structure of a part of the intestinal canal *.'

Domestic animals in South America have reverted to their original character.—It is well known that the horse, the ox, the boar, and other domestic animals, which have been introduced into South America, and have run wild in many parts, have entirely lost all marks of domesticity, and have reverted to the original characters of their species. But the dog has also become wild in Cuba, Hayti, and in all the Caribbean islands. In the course of the seventeenth century, they hunted in packs from twelve to fifty, or more in number, and fearlessly attacked herds of wild boars and other animals. It is natural, therefore, to inquire to what form they reverted? Now they are said by many travellers to have resembled very nearly the shepherd's dog; but it is certain that they were never turned into wolves. They were extremely savage, and their ravages appear to have been as much dreaded as those of wolves, but when any of their whelps were caught, and brought from the woods to the towns, they grew up in the most perfect submission to man.

Mummies of animals in Egyptian tombs identical with species still living.—As the advocates of the theory of transmutation trust much to the slow and insensible changes which time may work, they are accustomed to lament the absence of accurate descriptions, and figures of particular animals and plants, handed down from the earliest periods of history, such as might have afforded data for comparing the

* Prichard, Phys. Hist. of Mankind, vol. i. p. 96, who cites Professor Güldenstädt.

condition of species, at two periods considerably remote. But fortunately, we are in some measure independent of such evidence, for, by a singular accident, the priests of Egypt have bequeathed to us in their cemeteries, that information, which the museums and works of the Greek philosophers have failed to transmit.

For the careful investigation of these documents, we are greatly indebted to the skill and diligence of those naturalists who accompanied the French armies during their brief occupation of Egypt: that conquest of four years, from which we may date the improvement of the modern Egyptians in the arts and sciences, and the rapid progress which has been made of late in our knowledge of the arts and sciences of their remote predecessors. Instead of wasting their whole time, as so many preceding travellers had done, in exclusively collecting human mummies, M. Geoffroy and his associates examined diligently, and sent home great numbers of embalmed bodies of consecrated animals, such as the bull, the dog, the cat, the ape, the ichneumon, the crocodile, and the ibis.

To those who have never been accustomed to connect the facts of Natural History with philosophical speculations, who have never raised their conceptions of the end and import of such studies beyond the mere admiration of isolated and beautiful objects, or the exertion of skill in detecting specific differences, it will seem incredible that amidst the din of arms, and the stirring excitement of political movements, so much enthusiam could have been felt in regard to these precious remains.

In the official report drawn up by the Professors of the Museum at Paris, on the value of these objects, there are some eloquent passages which may appear extravagant, unless we reflect how fully these naturalists could appreciate the bearing of the facts thus brought to light on the past history of the globe.

'It seems,' say they, 'as if the superstition of the ancient Egyptians had been inspired by Nature, with a view of trans-

mitting to after ages a monument of her history. That extraordinary and whimsical people, by embalming with so much care the brutes which were the objects of their stupid adoration, have left us, in their sacred grottos, cabinets of zoology almost complete. The climate has conspired with the art of embalming to preserve the bodies from corruption, and we can now assure ourselves by our own eyes what was the state of a great number of species three thousand years ago. We can scarcely restrain the transports of our imagination, on beholding thus preserved, with their minutest bones, with the smallest portions of their skin, and in every particular most perfectly recognizable, many an animal, which at Thebes or Memphis, two or three thousand years ago, had its own priests and altars *.'

Among the Egyptian mummies thus procured were not only those of numerous wild quadrupeds, birds, and reptiles, but, what was perhaps of still greater importance in deciding the great question under discussion, there were the mummies of domestic animals, among which those above-mentioned, the bull, the dog, and the cat, were frequent. Now such was the conformity of the whole of these species to those now living, that there was no more difference, says Cuvier, between them than between the human mummies and the embalmed bodies of men of the present day. Yet some of these animals have since that period been transported by man to almost every variety of climate, and forced to accommodate their habits to new circumstances, as far as their nature would permit. The cat, for example, has been carried over the whole earth, and, within the last three centuries, has been naturalized in every part of the new world, from the cold regions of Canada to the tropical plains of Guiana; yet it has scarcely undergone any perceptible mutation, and is still the same animal which was held sacred by the Egyptians.

Of the ox, undoubtedly, there are many very distinct races;

* Ann. du Museum d'Hist. Nat., tom. i. p. 234. 1802. The reporters were MM. Cuvier, Lacépède, and Lamarck.

but the bull Apis, which was led in solemn processions by the Egyptian priests, did not differ from some of those now living. The black cattle that have run wild in America, where there were many peculiarities in the climate not to be found, perhaps, in any part of the old world, and where scarcely a single plant on which they fed was of precisely the same species, instead of altering their form and habits, have actually reverted to the exact likeness of the aboriginal wild cattle of Europe.

In answer to the arguments drawn from the Egyptian mummies, Lamarck said that they were identical with their living descendants in the same country, because the climate and physical geography of the banks of the Nile have remained unaltered for the last thirty centuries. But why, we ask, have other individuals of these species retained the same characters in so many different quarters of the globe, where the climate and many other conditions are so varied?

Seeds and Plants from the Egyptian tombs.—The evidence derived from the Egyptian monuments was not confined to the animal kingdom; the fruits, seeds, and other portions of twenty different plants, were faithfully preserved in the same manner; and among these the common wheat was procured by Delille, from closed vessels in the sepulchres of the kings, the grains of which retained not only their form but even their colour, so effectual has proved the process of embalming with bitumen in a dry and equable climate. No difference could be detected between this wheat and that which now grows in the East and elsewhere, and similar identifications were made in regard to all the other plants.

Native country of the common wheat.—And here we may observe, that there is an obvious answer to Lamarck's objection *, that the botanist cannot point out a country where the common wheat grows wild, unless in places where it may have been derived from neighbouring cultivation. All naturalists are well aware that the geographical distribution of a great

* Phil. Zool. tom. i., p. 227.

number of species is extremely limited, and that it was to be expected that every useful plant should first be cultivated successfully in the country where it was indigenous, and that, probably, every station which it partially occupied, when growing wild, would be selected by the agriculturist as best suited to it when artificially increased. Palestine has been conjectured, by a late writer on the Cerealia, to have been the original habitation of wheat and barley, a supposition which appears confirmed by Hebrew and Egyptian traditions, and by tracing the migrations of the worship of Ceres, as indicative of the migrations of the plant *.

If we are to infer that some one of the wild grasses has been transformed into the common wheat, and that some animal of the genus *canis*, still unreclaimed, has been metamorphosed into the dog, merely because we cannot find the domestic dog, or the cultivated wheat, in a state of nature, we may be next called upon to make similar admissions in regard to the camel; for it seems very doubtful whether any race of this species of quadruped is now wild.

Changes in Plants produced by cultivation.—But if agriculture, it will be said, does not supply examples of extraordinary changes of form and organization, the horticulturist can, at least, appeal to facts which may confound the preceding train of reasoning. The crab has been transformed into the apple; the sloe into the plum: flowers have changed their colour and become double; and these new characters can be perpetuated by seed,—a bitter plant with wavy sea-green leaves has been taken from the sea-side where it grew like wild charlock, has been transplanted into the garden, lost its saltness, and has been metamorphosed into two distinct vegetables as unlike each other as is each to the parent plant —the red cabbage and the cauliflower. These, and a multitude of analogous facts, are undoubtedly among the wonders of nature, and attest more strongly, perhaps, the extent to which species may be modified, than any examples derived

* L'Origine et la Patrie des Céréales, &c. Ann. des Sci. Nat. tom. ix., p. 61.

from the animal kingdom. But in these cases we find, that we soon reach certain limits, beyond which we are unable to cause the individuals, descending from the same stock, to vary; while, on the other hand, it is easy to show that these extraordinary varieties could seldom arise, and could never be perpetuated in a wild state for many generations, under any imaginable combination of accidents. They may be regarded as extreme cases brought about by human interference, and not as phenomena which indicate a capability of indefinite modification in the natural world.

The propagation of a plant by buds or grafts, and by cuttings, is obviously a mode which nature does not employ; and this multiplication, as well as that produced by roots and layers, seems merely to operate as an extension of the life of an individual, and not as a reproduction of the species, as happens by seed. All plants increased by the former means retain precisely the peculiar qualities of the individual to which they owe their origin, and like an individual, they have only a determinate existence; in some cases longer and in others shorter *. It seems now admitted by horticulturists, that none of our garden varieties of fruit are entitled to be considered strictly permanent, but that they wear out after a time †; and we are thus compelled to resort again to seeds; in which case there is so decided a tendency in the seedlings to revert to the original type, that our utmost skill is sometimes baffled in attempting to recover the desired variety.

Varieties of the Cabbage.—The different races of cabbages afford, as we have admitted, an astonishing example of deviation from a common type; but we can scarcely conceive them to have originated, much less to have lasted for several generations, without the intervention of man. It is only by strong manures that these varieties have been obtained, and in poorer soils they instantly degenerate. If,

* Smith's Introduction to Botany, p. 138. Edit. 1807.

† See Mr. Knight's Observations, Hort. Trans., vol. ii. p. 160.

therefore, we suppose in a state of nature the seed of the wild Brassica oleracea to have been wafted from the sea-side to some spot enriched by the dung of animals, and to have there become a cauliflower, it would soon diffuse its seed to some comparatively sterile soils around, and the offspring would relapse to the likeness of the parent stock, like some individuals which were seen growing in 1831 on the cornice of old London Bridge.

But if we go so far as to imagine the soil, in the spot first occupied, to be constantly manured by herds of wild animals, so as to continue as rich as that of a garden, still the variety could not be maintained, because we know that each of these races is prone to fecundate others, and gardeners are compelled to exert the utmost diligence to prevent cross-breeds. The intermixture of the pollen of varieties growing in the poorer soil around, would soon destroy the peculiar characters of the race which occupied the highly-manured tract; for, if these accidents so continually happen in spite of us among the culinary varieties, it is easy to see how soon this cause might obliterate every marked singularity in a wild state.

Besides, it is well-known that although the pampered races which we rear in our gardens for use or ornament may often be perpetuated by seed, yet they rarely produce seed in such abundance, or so prolific in quality, as wild individuals; so that if the care of man were withdrawn, the most fertile variety would always, in the end, prevail over the more steril.

Similar remarks may be applied to the double flowers which present such strange anomalies to the botanist. The ovarium, in such cases, is frequently abortive, and the seeds, when prolific, are generally much fewer than where the flowers are single.

Changes caused by soil.—Some curious experiments recently made on the production of blue instead of red flowers in the Hydrangea hortensis, illustrate the immediate effect of certain soils on the colours of the calyx and petals. In garden-mould

or compost, the flowers are invariably red; in some kinds of bog-earth they are blue; and the same change is always produced by a particular sort of yellow loam.

Varieties of the Primrose.—Linnæus was of opinion that the primrose, oxlip, cowslip, and polyanthus, were only varieties of the same species. The majority of modern botanists, on the contrary, consider them to be distinct, although some conceived that the oxlip might be a cross between the cowslip and the primrose. Mr. Herbert has lately recorded the following experiment:—"I raised from the natural seed of one umbel of a highly-manured red cowslip, a primrose, a cowslip, oxlips, of the usual and other colours, a black polyanthus, a hose-in-hose cowslip, and a natural primrose bearing its flower on a polyanthus stalk. From the seed of that very hose-in-hose cowslip I have since raised a hose-in-hose primrose. I therefore consider all these to be only local varieties depending upon soil and situation.*" Professor Henslow of Cambridge has since confirmed this experiment of Mr. Herbert, so that we have an example, not only of the remarkable varieties which the florist can obtain from a common stock, but of the distinctness of analogous races found in a wild state †.

On what particular ingredient, or quality in the earth, these changes depend, has not yet been ascertained ‡. But gardeners are well aware that particular plants, when placed under the influence of certain circumstances, are changed in various ways according to the species; and as often as the experiments are repeated similar results are obtained. The nature of these results, however, depends upon the species, and they are, therefore, part of the specific character; they exhibit the same phenomena again and again, and indicate certain fixed and invariable relations between the physiological peculiarities of the plant, and the influence of certain external agents. They afford no ground for questioning the instability

* Hort. Trans., vol. iv. p. 19.

† Loudon's Mag. of Nat. Hist., Sept. 1830, vol. iii. p. 408.

‡ Hort. Trans., vol. iii. p. 173.

of species, but rather the contrary; they present us with a class of phenomena which, when they are more thoroughly understood, may afford some of the best tests for identifying species, and proving that the attributes originally conferred, endure so long as any issue of the original stock remains upon the earth.

CHAPTER III.

Whether species have a real existence in Nature, *continued*—Variability of a species compared to that of an individual—Species which are susceptible of modification may be altered greatly in a short time, and in a few generations; after which they remain stationary—The animals now subject to man had originally an aptitude to domesticity—Acquired peculiarities which become hereditary have a close connexion with the habits or instincts of the species in a wild state—Some qualities in certain animals have been conferred with a view of their relation to man—Wild elephant domesticated in a few years, but its faculties incapable of further development.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE, *continued.*

Variability of a species compared to that of an individual.—We endeavoured in the last chapter to show, that a belief in the reality of species is not inconsistent with the idea of a considerable degree of variability in the specific character. This opinion, indeed, is little more than an extension of the idea which we must entertain of the identity of an individual, throughout the changes which it is capable of undergoing.

If a quadruped, inhabiting a cold northern latitude, and covered with a warm coat of hair or wool, be transported to a southern climate, it will often, in the course of a few years, shed a considerable portion of its coat, which it gradually recovers on being again restored to its native country. Even there the same changes are, perhaps, superinduced to a certain extent by the return of winter and summer. We know that the Alpine hare * and the ermine † become white during winter, and again obtain their full colour during the warmer season; that the plumage of the ptarmigan undergoes a like metamorphosis in colour and quantity, and that the change is equally temporary. We are aware that, if we reclaim some wild animal, and modify its habits and instincts by domestication, it may,

* Lepus variabilis.—Pallas. † Mustela erminea.—Linn.

if it escapes, become in a few years nearly as wild and untractable as ever; and if the same individual be again retaken, it may be reduced to its former tame state. A plant is placed in a prepared soil in order that the petals of its flowers may multiply, and their colour be heightened or changed; if we then withhold our care, the flowers of this same individual become again single. In these, and innumerable other instances, we must suppose that the individual was produced with a certain number of qualities; and, in the case of animals, with a variety of instincts, some of which may or may not be developed according to circumstances, or which, after having been called forth, may again become latent when the exciting causes are removed.

Now the formation of races seems the necessary consequence of such a capability in individuals to vary, if it be a general law that the offspring should very closely resemble the parent. But, before we can infer that there are no limits to the deviation from an original type which may be brought about in the course of an indefinite number of generations, we ought to have some proof that, in each successive generation, individuals may go on acquiring an equal amount of new peculiarities, under the influence of equal changes of circumstances. The balance of evidence, however, inclines most decidedly on the opposite side, for in all cases we find that the quantity of divergence diminishes from the first in a very rapid ratio.

Species which are susceptible of modification may be greatly altered in a few generations.—It cannot be objected, that it is out of our power to go on varying the circumstances in the same manner as might happen in the natural course of events during some great geological cycle. For in the first place, where a capacity is given to individuals to adapt themselves to new circumstances, it does not generally require a very long period for its development; if, indeed, such were the case, it is not easy to see how the modification would answer the ends proposed, for all the individuals would die before new qualities, habits, or instincts were conferred.

When we have succeeded in naturalizing some tropical plant in a temperate climate, nothing prevents us from attempting gradually to extend its distribution to higher latitudes, or to greater elevations above the level of the sea, allowing equal quantities of time, or an equal number of generations for habituating the species to successive increments of cold. But every husbandman and gardener is aware that such experiments will fail; and we are more likely to succeed in making some plants, in the course of the first two generations, support a considerable degree of difference of temperature than a very small difference afterwards, though we persevere for many centuries.

It is the same if we take any other cause instead of temperature; such as the quality of the food, or the kind of dangers to which an animal is exposed, or the soil in which a plant lives. The alteration in habits, form, or organization, is often rapid during a short period; but when the circumstances are made to vary further, though in ever so slight a degree, all modification ceases, and the individual perishes. Thus some herbivorous quadrupeds may be made to feed partially on fish or flesh, but even these can never be taught to live on some herbs which they reject, and which would even poison them, although the same may be very nutritious to other species of the same natural order. So when man uses force or stratagem against wild animals, the persecuted race soon becomes more cautious, watchful, and cunning; new instincts seem often to be developed, and to become hereditary in the first two or three generations; but let the skill and address of man increase, however gradually, no further variation can take place, no new qualities are elicited by the increasing dangers. The alteration of the habits of the species has reached a point beyond which no ulterior modification is possible, however indefinite the lapse of ages during which the new circumstances operate. Extirpation then follows, rather than such a transformation as could alone enable the species to perpetuate itself under the new state of things.

Animals now subject to man had originally an aptitude to domesticity.—It has been well observed by M. F. Cuvier and M. Dureau de la Malle, that unless some animals had manifested in a wild state an aptitude to second the efforts of man, their domestication would never have been attempted. If they had all resembled the wolf, the fox, and the hyæna, the patience of the experimentalist would have been exhausted by innumerable failures before he at last succeeded in obtaining some imperfect results; so, if the first advantages derived from the cultivation of plants had been elicited by as tedious and costly a process as that by which we now make some slight additional improvement in certain races, we should have remained to this day in ignorance of the greater number of their useful qualities.

Acquired instincts of some animals become hereditary.—It is undoubtedly true, that many new habits and qualities have not only been acquired in recent times by certain races of dogs, but have been transmitted to their offspring. But in these cases it will be observed, that the new peculiarities have an intimate relation to the habits of the animal in a wild state, and therefore do not attest any tendency to departure to an indefinite extent from the original type of the species. A race of dogs employed for hunting deer in the platform of Santa Fé in Mexico, affords a beautiful illustration of a new hereditary instinct. The mode of attack, observes M. Roulin, which they employ, consists in seizing the animal by the belly and overturning it by a sudden effort, taking advantage of the moment when the body of the deer rests only upon the fore-legs. The weight of the animal thus thrown over, is often six times that of its antagonist. The dog of pure breed inherits a disposition to this kind of chase, and never attacks a deer from before while running. Even should the latter, not perceiving him, come directly upon him, the dog steps aside and makes his assault on the flank, whereas other hunting-dogs, though of superior strength and general sagacity, which are brought from Europe, are destitute of this instinct. For want of similar

precautions, they are often killed by the deer on the spot, the vertebræ of their neck being dislocated by the violence of the shock *.

A new instinct has also become hereditary in a mongrel race of dogs employed by the inhabitants of the banks of the Magdalena almost exclusively in hunting the white-lipped pecari. The address of these dogs consists in restraining their ardour, and attaching themselves to no animal in particular, but keeping the whole herd in check. Now, among these dogs some are found, which, the very first time they are taken to the woods, are acquainted with this mode of attack; whereas, a dog of another breed starts forward at once, is surrounded by the pecari, and whatever may be his strength is destroyed in a moment.

Some of our countrymen, engaged of late in conducting the principal mining associations in Mexico †, carried out with them some English greyhounds of the best breed to hunt the hares which abound in that country. The great platform which is the scene of sport is at an elevation of about nine thousand feet above the level of the sea, and the mercury in the barometer stands habitually at the height of about nineteen inches. It was found that the greyhounds could not support the fatigues of a long chase in this attenuated atmosphere, and before they could come up with their prey, they lay down gasping for breath; but these same animals have produced whelps which have grown up, and are not in the least degree incommoded by the want of density in the air, but run down the hares with as much ease as the fleetest of their race in this country.

The fixed and deliberate stand of the pointer has with propriety been regarded as a mere modification of a habit, which may have been useful to a wild race accustomed to wind game, and steal upon it by surprise, first pausing for an instant in order to spring with unerring aim. The faculty of the Re-

* M. Roulin, Ann. des Sci. Nat., tom. xvi. p. 16, 1829.

† The Real del Monte Company.

triever, however, may justly be regarded as more inexplicable and less easily referrible to the instinctive passions of the species. M. Majendie, says a French writer in a recently-published memoir, having learnt that there was a race of dogs in England, which stopped and brought back game of their own accord, procured a pair, and having obtained a whelp from them kept it constantly under his eyes, until he had an opportunity of assuring himself that, without having received any instruction, and on the very first day that it was carried to the chase, it brought back game with as much steadiness as dogs which had been schooled into the same manœuvre by means of the whip and collar.

Such attainments, as well as the habits and dispositions which the shepherd's dog and many others inherit, seem to be of a nature and extent which we can hardly explain by supposing them to be modifications of instincts necessary for the preservation of the species in a wild state. When such remarkable habits appear in races of this species, we may reasonably conjecture that they were given with no other view than for the use of man and the preservation of the dog, which thus obtains protection.

Attributes of animals in their relation to man.—As a general rule, we fully agree with M. F. Cuvier that, in studying the habits of animals, we must attempt, as far as possible, to refer their domestic qualities to modifications of instincts which are implanted in them in a state of nature; and that writer has successfully pointed out, in an admirable essay on the domestication of the mammalia, the true origin of many dispositions which are vulgarly attributed to the influence of education alone *. But we should go too far if we did not admit that some of the qualities of particular animals and plants may have been given solely with a view to the connexion which it was foreseen would exist between them and man—especially when we see that connexion to be in many

* Mem. du Mus. d'Hist. Nat.—Jameson, Ed. New Phil. Journ., Nos. 6, 7, 8.

cases so intimate, that the greater number, and sometimes all the individuals of the species which exist on the earth, are in subjection to the human race.

We can perceive in a multitude of animals, especially in some of the parasitic tribes, that certain instincts and organs are conferred for the purpose of defence or attack against some other species. Now if we are reluctant to suppose the existence of similar relations between man and the instincts of many of the inferior animals, we adopt an hypothesis no less violent, though in the opposite extreme to that which has led some to imagine the whole animate and inanimate creation to have been made solely for the support, gratification, and instruction of mankind.

Many species most hostile to our persons or property multiply in spite of our efforts to repress them; others, on the contrary, are intentionally augmented many hundred-fold in number by our exertions. In such instances we must imagine the relative resources of man and of species, friendly or inimical to him, to have been prospectively calculated and adjusted. To withhold assent to this supposition would be to refuse what we must grant in respect to the economy of Nature in every other part of the organic creation; for the various species of contemporary plants and animals have obviously their relative forces nicely balanced, and their respective tastes, passions, and instincts so contrived, that they are all in perfect harmony with each other. In no other manner could it happen that each species, surrounded as it is by countless dangers, should be enabled to maintain its ground for periods of considerable duration.

The docility of the individuals of some of our domestic species extending, as it does, to attainments foreign to their natural habits and faculties, may perhaps have been conferred with a view to their association with man. But lest species should be thereby made to vary indefinitely, we find that such habits are never transmissible by generation.

A pig has been trained to hunt and point game with great

activity and steadiness *; and other learned individuals, of the same species, have been taught to spell; but such fortuitous acquirements never become hereditary, for they have no relation whatever to the exigencies of the animal in a wild state, and cannot therefore be developments of any instinctive propensities.

Influence of domestication.—An animal in domesticity, says M. F. Cuvier, is not essentially in a different situation in regard to the feeling of restraint from one left to itself. It lives in society without constraint, because without doubt it was a social animal, and it conforms itself to the will of man, because it had a chief to which in a wild state it would have yielded obedience. There is nothing in its new situation that is not conformable to its propensities; it is satisfying its wants by submission to a master, and makes no sacrifice of its natural inclinations. All the social animals when left to themselves form herds more or less numerous, and all the individuals of the same herd know each other, are mutually attached, and will not allow a strange individual to join them. In a wild state, moreover, they obey some individual, which by its superiority has become the chief of the herd. Our domestic species had originally this sociability of disposition, and no solitary species, however easy it may be *to tame it*, has yet afforded true domestic races. We merely, therefore, develope to our own advantage, propensities which propel the individuals of certain species to draw near to their fellows.

The sheep which we have reared is induced to follow us, as it would be led to follow the flock among which it was brought up; and when individuals of gregarious species have been accustomed to one master, it is he alone whom they acknowledge as their chief, he only whom they obey.—'The elephant only allows himself to be led by the carnac whom he has adopted; the dog itself, reared in solitude with its master, manifests a hostile disposition towards all others; and every-

* In the New Forest, near Ringwood, Hants, by Mr. Toomer, keeper of Broomy Lodge.

body knows how dangerous it is to be in the midst of a herd of cows, in pasturages that are little frequented, when they have not at their head the keeper who takes care of them.'

'Everything, therefore, tends to convince us that formerly men were only, with regard to the domestic animals, what those who are particularly charged with the care of them still are, namely members of the society, which these animals form among themselves, and that they are only distinguished in the general mass by the authority which they have been enabled to assume from their superiority of intellect. Thus, every social animal which recognizes man as a member, and as the chief of its herd, is a domestic animal. It might even be said that from the moment when such an animal admits man as a member of its society, it is domesticated, as man could not enter into such a society without becoming the chief of it *.'

But the ingenious author whose observations we have here cited, admits that the obedience which the individuals of many domestic species yield indifferently to every person is without analogy in any state of things which could exist previously to their subjugation by man. Each troop of wild horses, it is true, has some stallion for its chief, who draws after him all the individuals of which the herd is composed; but when a domesticated horse has passed from hand to hand, and has served several masters, he becomes equally docile towards *any person*, and is subjected to the whole human race. It seems fair to presume, that the capability in the instinct of the horse to be thus modified, was given to enable the species to render greater services to man; and, perhaps, the facility with which many other acquired characters become hereditary in various races of the horse, may be explicable only on a like supposition. The amble, for example, a pace to which the domestic races in Spanish America are exclusively trained, has in the course of several generations, become hereditary, and is assumed by all the young colts before they are broken in †.

* Mem. du Mus. d'Hist. Nat.

† Dureau de la Malle, Ann. des Sci. Nat., tom. xxi. p. 58.

It seems also reasonable to conclude, that the power bestowed on the horse, the dog, the ox, the sheep, the cat, and many species of domestic fowls, of supporting almost every climate, was given expressly to enable them to follow man throughout all parts of the globe—in order that we might obtain their services, and they our protection. If it be objected that the elephant, which, by the union of strength, intelligence, and docility, can render the greatest services to mankind, is incapable of living in any but the warmest latitudes, we may observe, that the quantity of vegetable food required by this quadruped would render its maintenance, in the temperate zone too costly, and in the arctic impossible.

Among the changes superinduced by man, none appear at first sight more remarkable than the perfect tameness of certain domestic races. It is well known that, at however early an age we obtain possession of the young of many unreclaimed races, they will retain throughout life a considerable timidity and apprehensiveness of danger; whereas, after one or two generations, the descendants of the same will habitually place the most implicit confidence in man. There is good reason, however, to suspect that such changes are not without analogy in a state of nature, or, to speak more correctly, in situations where man has not interfered.

Thus, Dr. Richardson informs us, in his able history of the habits of North American animals, that, 'in the retired parts of the mountains, where the hunters had seldom penetrated, there is no difficulty in approaching the Rocky Mountain sheep, which there exhibit *the simplicity of character so remarkable in the domestic species;* but where they have been often fired at, they are exceedingly wild, alarm their companions, on the approach of danger, by a hissing noise, and scale the rocks with a speed and agility that baffles pursuit *.'

It is probable, therefore, that as man, in diffusing himself over the globe, has tamed many wild races, so also he has made

* Fauna Boreali-Americana, p. 273.

many tame races wild. Had some of the larger carnivorous beasts, capable of scaling the rocks, made their way into the North American mountains before our hunters, a similar alteration in the instincts of the sheep would doubtless have been brought about.

Wild elephants domesticated in a few years.—No animal affords a more striking illustration of the principal points we have been endeavouring to establish than the elephant. For, in the first place, the wonderful sagacity with which he accommodates himself to the society of man, and the new habits which he contracts, are not the result of time nor of modifications produced in the course of many generations. These animals will breed in captivity, as is now ascertained in opposition to the vulgar opinion of many modern naturalists, and in conformity to that of the ancients Ælian and Columella *. Yet it has always been the custom, as the least expensive mode of obtaining them, to capture wild individuals in the forests, usually when full grown, and in a few years after they are taken, sometimes, it is said, in the space of a few months, their education is completed.

Had the whole species been domesticated from an early period in the history of man, like the camel, their superior intelligence would doubtless have been attributed to their long and familiar intercourse with the lord of the creation: but we know that a few years is sufficient to bring about this wonderful change of habits; and, although the same individual may continue to receive tuition for a century afterwards, yet it makes no further progress in the general development of its faculties. Were it otherwise, indeed, the animal would soon deserve more than the poet's epithet of 'half-reasoning.'

From the authority of our countrymen employed in the late Burmese war, it appears, in corroboration of older accounts, that, when elephants are required to execute extraordinary

* Mr. Corse on the Habits, &c., of the Elephant, Phil. Trans., 1799.

tasks, they may be made to understand that they will receive unusual rewards. Some favourite dainty is shown to them, in the hope of acquiring which the work is done. And so perfectly does the nature of the contract appear to be understood, that the breach of it on the part of the master is often attended with danger. In this case, a power has been given to the species to adapt their social instincts to new circumstances with surprising rapidity; but the extent of this change is defined by strict and arbitrary limits. There is no indication of a tendency to continued divergence from certain attributes with which the elephant was originally endued, no ground whatever for anticipating that, in thousands of centuries, any material alteration could ever be effected. All that we can infer from analogy is, that some useful and peculiar races might probably be formed, if the experiment were fairly tried, and that some individual characteristic, now only casual and temporary, might be perpetuated by generation.

In all cases, therefore, where the domestic qualities exist in animals, they seem to require no lengthened process for their development, and they appear to have been wholly denied to some classes, which from their strength and social nature might have rendered great services to man; as, for example, the greater part of the quadrumana. The orang-outang, indeed, which, for its resemblance in form to man, and apparently for no other good reason, has been assumed by Lamarck to be the most perfect of the inferior animals, has been tamed by the savages of Borneo, and made to climb lofty trees, and to bring down the fruit. But he is said to yield to his masters an unwilling obedience, and to be held in subjection only by severe discipline. We know nothing of the faculties of this animal which can suggest the idea that it rivals the elephant in intelligence, much less anything which can countenance the dreams of those who have fancied that it might have been transmuted into 'the dominant race.' One of the baboons of Sumatra (*Simia carpolegus*) appears to be more docile, and is frequently trained by the inhabitants to ascend

trees for the purpose of gathering cocoa-nuts, a service in which the animal is very expert. He selects, says Sir Stamford Raffles, the ripe nuts with great judgment, and pulls no more than he is ordered *. The capuchin and cacajao monkeys are, according to Humboldt, taught to ascend trees in the same manner, and to throw down fruit on the banks of the lower Orinoco †.

We leave it to the Lamarckians to explain how it happens that those same savages of Borneo have not themselves acquired, by dint of longing for many generations for the power of climbing trees, the elongated arms of the orang, or even the prehensile tails of some American monkeys. Instead of being reduced to the necessity of subjugating stubborn and untractable brutes, we should naturally have anticipated 'that their wants would have excited them to efforts, and that continued efforts would have given rise to new organs;' or, rather, to the re-acquisition of organs which, in a manner irreconcileable with the principle of the *progressive* system, have grown obsolete in tribes of men which have such constant need of them.

Recapitulation.—It follows, then, from the different facts which we have considered in this chapter, that a short period of time is generally sufficient to effect nearly the whole change which an alteration of external circumstances can bring about in the habits of a species, and that such capacity of accommodation to new circumstances is enjoyed in very different degrees by different species.

Certain qualities appear to be bestowed exclusively with a view to the relations which are destined to exist between different species, and, among others, between certain species and man; but these latter are always so nearly connected with the original habits and propensities of each species in a wild state,

* Linn. Trans., vol. xiii. p. 244.

† Pers. Narr. of Travels to the Equinoctial Regions of the New Continent in the years 1799-1804.

that they imply no indefinite capacity of varying from the original type. The acquired habits derived from human tuition are rarely transmitted to the offspring; and when this happens, it is almost universally the case with those merely which have some obvious connexion with the attributes of the species when in a state of independence.

CHAPTER IV.

Consideration of the question whether species have a real existence in nature, *continued*—Phenomena of hybrids—Hunter's opinions as to mule animals—Mules not strictly intermediate between the parent species—Hybrid plants—Experiments of Kölreuter—The same repeated by Weigmann—Vegetable hybrids prolific throughout several generations—Why so rare in a wild state—De Candolle's opinion respecting hybrid plants—The phenomena of hybrids confirms the doctrine of the permanent distinctness of species—Theory of the gradation in the intelligence of animals as indicated by the facial angle—Discovery of Tiedemann that the brain of the fœtus in mammalia assumes successively the form of the brain of a fish, reptile, and bird—Bearing of this discovery on the theory of progressive development and transmutation—Recapitulation.

WHETHER SPECIES HAVE A REAL EXISTENCE IN NATURE, *continued.*

Phenomena of hybrids.—We have yet to consider another class of phenomena, those relating to the production of hybrids, which have been regarded in a very different light with reference to their bearing on the question of the permanent distinctness of species; some naturalists considering them as affording the strongest of all proofs in favour of the reality of species; others, on the contrary, appealing to them as countenancing the opposite doctrine, that all the varieties of organization and instinct now exhibited in the animal and vegetable kingdoms, may have been propagated from a small number of original types.

HYBRID ANIMALS.

In regard to the mammifers and birds, it is found that no sexual union will take place between races which are remote from each other in their habits and organization; and it is only in species that are very nearly allied that such unions produce offspring. It may be laid down as a general rule, admitting of very few exceptions among quadrupeds, that the

hybrid progeny is steril, and there seem to be no well-authenticated examples of the continuance of the mule race beyond one generation. The principal number of observations and experiments relate to the mixed offspring of the horse and the ass; and in this case it is well established that the he-mule can generate, and the she-mule produce. Such cases occur in Spain and Italy, and much more frequently in the West Indies and New Holland; but these mules have never bred in cold climates, seldom in warm regions, and still more rarely in temperate countries.

The hybrid offspring of the she-ass and the stallion, the γιννος of Aristotle, and the hinnus of Pliny, differs from the mule, or the offspring of the ass and mare. In both cases, says Buffon, these animals retain more of the dam than of the sire, not only in the magnitude but in the figure of the body; whereas, in the form of the head, limbs, and tail, they bear a greater resemblance to the sire. The same naturalist infers, from various experiments respecting cross-breeds between the he-goat and ewe, the dog and she-wolf, the goldfinch and canary-bird, that the male transmits his sex to the greatest number, and that the preponderance of males over females exceeds that which prevails where the parents are of the same species.

Hunter's opinion.—The celebrated John Hunter has observed, that the true distinction of species must ultimately be gathered from their incapacity of propagating with each other, and producing offspring capable of again continuing itself. He was unwilling, however, to admit that the horse and the ass were of the same species, because some rare instances had been adduced of the breeding of mules, which he attributed to a degree of monstrosity in the organs of the mule, for these he suggested might not have been those of a mixed animal, but those of the mare or female ass. 'This,' he argues, 'is not a far-fetched idea, for true species produce monsters, and many animals of distinct sex are incapable of breeding at all; and as we find nature, in its greatest perfection, deviating from gene-

ral principles, why may it not happen likewise in the production of mules, so that sometimes a mule shall breed from the circumstance of its being a monster respecting mules?'

That the dog, wolf, and jackal are the same species.—Yet, in the same memoir, this great anatomist inferred that the wolf, the dog, and the jackal were all of one species, because he had found, by two experiments, that the dog would breed both with the wolf and the jackal; and that the mule, in each case, would breed again with the dog. In these cases, however, we may observe that there was always one parent at least of pure breed, and no proof was obtained that a true hybrid race could be perpetuated; a fact of which we believe no examples are yet recorded, either in regard to mixtures of the horse and ass, or any other of the mammalia.

Should the fact be hereafter ascertained, that two mules can propagate their kind, we must still inquire whether the offspring may not be regarded in the light of a monstrous birth, proceeding from some accidental cause, or rather, to speak more philosophically, from some general law not yet understood, but which may not be permitted permanently to interfere with those laws of generation, whereby species may, in general, be prevented from becoming blended. If, for example, we discovered that the progeny of a mule race degenerated greatly in the first generation, in force, sagacity, or any attribute necessary for its preservation in a state of nature, we might infer that, like a monster, it is a mere temporary and fortuitous variety. Nor does it seem probable that the greater number of such monsters could ever occur unless obtained by art; for in Hunter's experiments, stratagem or force was, in most instances, employed to bring about the irregular connexion *.

Mules not strictly intermediate between the parent species.—It seems rarely to happen that the mule offspring is truly intermediate in character between the two parents. Thus Hunter mentions that, in his experiments, one of the hybrid

* Phil. Trans., 1787. Additional Remarks, Phil. Trans., 1789.

pups resembled the wolf much more than the rest of the litter; and we are informed by Wiegmann that, in a litter lately obtained in the Royal Menagerie at Berlin, from a white pointer and a she-wolf, two of the cubs resembled the common wolf-dog, but the third was like a pointer with hanging ears.

There is undoubtedly a very close analogy between these phenomena and those presented by the intermixture of distinct races of the same species, both in the inferior animals and in man. Dr. Prichard, in his 'Physical History of Mankind,' cites examples where the peculiarities of the parents have been transmitted very unequally to the offspring; as where children, entirely white, or perfectly black, have sprung from the union of the European and the negro. Sometimes the colour, or other peculiarities of one parent, after having failed to show themselves in the immediate progeny, reappear in a subsequent generation, as where a white child is born of two black parents, the grandfather having been a white *.

The same author judiciously observes that, if different species mixed their breed, and hybrid races were often propagated, the animal world would soon present a scene of confusion; its tribes would be everywhere blended together, and we should perhaps find more hybrid creatures than genuine and uncorrupted races †.

HYBRID PLANTS.

Kölreuter's experiments.—The history of the vegetable kingdom has been thought to afford more decisive evidence in favour of the theory of the formation of new and permanent species from hybrid stocks. The first accurate experiments in illustration of this curious subject appear to have been made by Kölreuter, who obtained a hybrid from two species of tobacco, *Nicotiana rustica* and *N. paniculata,* which differ greatly in the shape of their leaves, the colour of the corolla, and the height of the stem. The stigma of a female plant of

* Vol. i. p. 217. † Ibid., vol. i. p. 97.

N. rustica was impregnated with the pollen of a male plant of *N. paniculata.* The seed ripened and produced a hybrid which was intermediate between the two parents, and which, like all the hybrids which this botanist brought up, had imperfect stamens. He afterwards impregnated this hybrid with the pollen of *N. paniculata,* and obtained plants which much more resembled the last. This he continued through several generations, until, by due perseverance, he actually changed the *Nicotiana rustica* into the *Nicotiana paniculata.*

The plan of impregnation adopted was the cutting off of the anthers of the plant intended for fructification before they had shed pollen, and then laying on foreign pollen upon the stigma.

Wiegmann's experiments.—The same experiment has since been repeated with success by Wiegmann, who found that h could bring back the hybrids to the exact likeness of either parent, by crossing them a sufficient number of times.

The blending of the characters of the parent stocks, in many other of Wiegmann's experiments, was complete; the colour and shape of the leaves and flowers, and even the scent, being intermediate, as in the offspring of the two species of verbascum. An intermarriage, also, between the common onion and the leek (*Allium cepa* and *A. porrum*) gave a mule plant, which, in the character of its leaves and flowers, approached most nearly to the garden onion, but had the elongated bulbous root and smell of the leek.

The same botanist remarks that vegetable hybrids, when not strictly intermediate, more frequently approach the female than the male parent species, *but they never exhibit characters foreign to both.* A recross with one of the original stocks generally causes the mule plant to revert towards that stock; but this is not always the case, the offspring sometimes continuing to exhibit the character of a full hybrid.

In general, the success attending the production and perpetuity of hybrids among plants depends, as in the animal kingdom, on the degree of proximity between the species inter-

married. If their organization be very remote, impregnation never takes place; if somewhat less distant, seeds are formed, but always imperfect and steril. The next degree of relationship yields hybrid seedlings, but these are barren; and it is only when the parent species are very nearly allied that the hybrid race may be perpetuated for several generations. Even in this case, the best authenticated examples seem confined to the crossing of hybrids with individuals of pure breed. In none of the experiments most accurately detailed does it appear that both the parents were mules.

Wiegmann diversified as much as possible his mode of bringing about these irregular unions among plants. He often sowed parallel rows, near to each other, of the species from which he desired to breed, and instead of mutilating, after Kölreuter's fashion, the plants of one of the parent stocks, he merely washed the pollen off their anthers. The branches of the plants in each row were then gently bent towards each other and intertwined, so that the wind, and numerous insects, as they passed from the flowers of one to those of the other species, carried the pollen and produced fecundation.

Vegetable hybrids why rare in a wild state.—The same observer saw a good exemplification of the manner in which hybrids may be formed in a state of nature. Some wallflowers and pinks had been growing in a garden, in a dry sunny situation, and their stigmas had been ripened so as to be moist, and to absorb pollen with avidity, although their anthers were not yet developed. These stigmas became impregnated by pollen blown from some other adjacent plants of the same species, but had they been of different species, and not too remote in their organization, mule races must have resulted.

When, indeed, we consider how busily some insects have been shown to be engaged in conveying anther-dust from flower to flower, especially bees, flower-eating beetles, and the like, it seems a most enigmatical problem how it can happen that promiscuous alliances between distinct species are not perpetually occurring.

How continually do we observe the bees diligently employed in collecting the red and yellow powder by which the stamens of flowers are covered, loading it on their hind legs, and carrying it to their hive for the purpose of feeding their young! In thus providing for their own progeny, these insects assist materially the process of fructification *. Few of our readers need be reminded that the stamens in certain plants grow on different blossoms from the pistils, and unless the summit of the pistil be touched with the fertilizing dust, the fruit does not swell, nor the seed arrive at maturity. It is by the help of bees chiefly, that the development of the fruit of many such species is secured, the powder which they have collected from the stamens being unconsciously left by them in visiting the pistils.

How often, during the heat of a summer's day, do we see the males of diœcious plants, such as the yew-tree, standing separate from the females, and sending off into the air, upon the slightest breath of wind, clouds of buoyant pollen! That the zephyr should so rarely intervene to fecundate the plants of one species with the anther dust of others, seems almost to realize the converse of the miracle believed by the credulous herdsmen of the Lusitanian mares—

> Ore omnes versæ in Zephyrum, stant rupibus altis,
> Exceptantque leves auras: et sæpe sine ullis
> Conjugiis, vento gravidæ, mirabile dictu †.

But, in the first place, it appears that there is a natural aversion in plants, as well as in animals, to irregular sexual unions; and in most of the successful experiments in the animal and vegetable world, some violence has been used in order to procure impregnation. The stigma imbibes, slowly and reluctantly, the granules of the pollen of another species, even when it is abundantly covered with it; and if it happen that, during this period, ever so slight a quantity of the anther-dust of its own species alight upon it, this is instantly absorbed, and the effect of the foreign pollen destroyed. Besides, it does

* See Barton on the Geography of Plants, p. 67.

† Georg. lib. iii. 273.

not often happen that the male and female organs of fructification, in different species, arrive at a state of maturity at precisely the same time. Even where such synchronism does prevail, so that a cross impregnation is effected, the chances are very numerous against the establishment of a hybrid race.

If we consider the vegetable kingdom generally, it must be recollected, that even of the seeds which are well ripened, the greater part are either eaten by insects, birds, and other animals, or decay for want of room and opportunity to germinate. Unhealthy plants are the first which are cut off by causes prejudicial to the species, being usually stifled by more vigorous individuals of their own kind. If, therefore, the relative fecundity or hardiness of hybrids be in the least degree inferior, they cannot maintain their footing for many generations, even if they were ever produced beyond one generation in a wild state. In the universal struggle for existence, the right of the strongest eventually prevails; and the strength and durability of a race depends mainly on its prolificness, in which hybrids are acknowledged to be deficient.

Centaurea hybrida, a plant which never bears seed, and is supposed to be produced by the frequent intermixture of two well-known species of Centaurea, grows wild upon a hill near Turin. *Ranunculus lacerus*, also steril, has been produced accidentally at Grenoble, and near Paris, by the union of two Ranunculi; but this occurred in gardens *.

Mr. Herbert's experiments—Mr. Herbert in one of his ingenious papers on mule plants, endeavours to account for their non-occurrence in a state of nature, from the circumstance that all the combinations that were likely to occur, have already been made many centuries ago, and have formed the various species of botanists; but in our gardens, he says, whenever species, having a certain degree of affinity to each other, are transported from different countries, and brought for the first time into contact, they give rise to hybrid species †. But we have no data, as yet, to warrant the conclusion, that a single

* Hon. and Rev. W. Herbert, Hort. Trans., vol. iv., p. 41. † Ibid.

permanent hybrid race has ever been formed, even in gardens, by the intermarriage of two allied species brought from distant habitations. Until some fact of this kind is fairly established, and a new species, capable of perpetuating itself in a state of perfect independence of man, can be pointed out, we think it reasonable to call in question entirely this hypothetical source of new species. That varieties do sometimes spring up from cross breeds, in a natural way, can hardly be doubted, but they probably die out even more rapidly than races propagated by grafts or layers.

Opinions of De Candolle respecting hybrid plants.—De Candolle, whose opinion on a philosophical question of this kind deserves the greatest attention, has observed, in his Essay on Botanical Geography, that the *varieties* of plants range themselves under two general heads: those produced by external circumstances, and those formed by hybridity. After adducing various arguments to show that neither of these causes can explain the permanent diversity of plants indigenous in different regions, he says, in regard to the crossing of races, 'I can perfectly comprehend, without altogether sharing the opinion, that where many species of the same genera occur near together, hybrid species may be formed, and I am aware that the great number of species of certain genera which are found in particular regions may be explained in this manner; but I am unable to conceive how any one can regard the same explanation as applicable to species which live naturally at great distances. If the three larches, for example, now known in the world, lived in the same localities, I might then believe that one of them was the produce of the crossing of the two others; but I never could admit that the Siberian species has been produced by the crossing of those of Europe and America. I see, then, that there exist, in organized beings, permanent differences which cannot be referred to any one of the actual causes of variation, and these differences are what constitute *species* *.'

* Essai Elémentaire, &c. 3me. partie.

Distinctness of species confirmed by the phenomena of hybrids.—The most decisive arguments, perhaps, amongst many others, against the probability of the derivation of permanent species from cross breeds, are to be drawn from the fact alluded to by De Candolle, of species having a close affinity to each other occurring in distinct botanical provinces, or countries inhabited by groups of distinct species of indigenous plants. For in this case naturalists who are not prepared to go the whole length of the transmutationists, are under the necessity of admitting, that in some cases species which approach very near to each other in their characters, were so created from their origin; an admission fatal to the idea of its being a general law of nature, that a few original types only should be formed, and that all intermediate races should spring from the intermixture of those stocks.

This notion, indeed, is wholly at variance with all that we know of hybrid generation; for the phenomena entitle us to affirm, that had the types been at first somewhat distant, *no cross-breeds would ever have been produced,* much less those prolific races which we now recognise as distinct species.

Difficulties attending the propagation of hybrid races.—In regard, moreover, to the permanent propagation of hybrid races among animals, insuperable difficulties present themselves, when we endeavour to conceive the blending together of the different instincts and propensities of two species, so as to insure the preservation of the intermediate race. The common mule, when obtained by human art, may be protected by the power of man; but in a wild state, it would neither have precisely the same wants as the horse or the ass: and if, in consequence of some difference of this kind, it strayed from the herd, it would soon be hunted down by beasts of prey and destroyed.

If we take some genus of insects, such as the bee, we find that each of the numerous species has some difference in its habits, its mode of collecting honey, or constructing its dwelling, or providing for its young, and other particulars. In

the case of the common hive-bee, the workers are described, by Kirby and Spence, as being endowed with no less than thirty distinct instincts *. So also we find that amongst a most numerous class of spiders, there are nearly as many different modes of spinning their webs as there are species. When we recollect how complicated are the relations of these instincts with co-existing species, both of the animal and vegetable kingdoms, it is scarcely possible to imagine that a bastard race could spring from the union of two of these species, and retain just so much of the qualities of each parent stock as to preserve its ground in spite of the dangers which surround it.

We should also ask, if a few generic types alone have been *created* among insects, and the intermediate species have proceeded from hybridity, where are those original types, combining, as they ought to do, the elements of all the instincts which have made their appearance in the numerous derivative races? So also in regard to animals of all classes, and of plants; if species in general are of hybrid origin, where are the stocks which combine in themselves the habits, properties, and organs, of which all the intervening species ought to afford us mere modifications?

Recapitulation of the arguments from hybrids.—Weshal l now conclude this subject by summing up, in a few words, the results to which the consideration of the phenomena of hybrids has led us. It appears that the aversion of individuals of distinct species to the sexual union is common to animals and plants, and that it is only when the species approach near to each other in their organization and habits, that any offspring are produced from their connexion. Mules are of extremely rare occurrence in a state of nature, and no examples are yet known of their having procreated in a wild state. But it has been proved, that hybrids are not universally steril, provided the parent stocks have a near affinity to each other, although the continuation of the mixed race, for several generations,

* Intr. to Entom., vol. ii., p. 504. Ed. 1817.

appears hitherto to have been obtained only by crossing the hybrids with individuals of pure species, an experiment which by no means bears out the hypothesis that a true hybrid race could ever be permanently established.

Hence we may infer, that aversion to sexual intercourse is, in general, a good test of the distinctness of original stocks, or of *species*, and the procreation of hybrids is a proof of the very near affinity of species. Perhaps, hereafter, the number of generations for which hybrids may be continued, before the race dies out (for it seems usually to degenerate rapidly), may afford the zoologist and botanist an experimental test of the difference in the degree of affinity of allied species.

We may also remark, that if it could have been shown that a single permanent species had ever been produced by hybridity (of which there is no satisfactory proof), it might certainly have lent some countenance to the notions of the ancients respecting the gradual deterioration of created things, but none whatever to Lamarck's theory of their progressive perfectibility; for observations have hitherto shown that there is a tendency, in mule animals and plants, to degenerate in organization.

We have already remarked, that the theory of progressive development arose from an attempt to ingraft the doctrines of the transmutationists upon one of the most popular generalizations in geology. But modern geological researches have almost destroyed every appearance of that gradation in the successive groups of animate beings, which was supposed to indicate the slow progress of the organic world from the more simple to the more compound structure. In the more modern formations, we find clear indications that the highest orders of the terrestrial mammalia were fully represented during several successive epochs; but in the monuments which we have hitherto examined of more remote eras, in which there are as yet discovered few fluviatile, and perhaps no lacustrine formations, and, therefore, scarcely any means of obtaining an insight into the zoology

of the then existing continents, we have only as yet found one example of a mammiferous quadruped. The recent origin of man, and the absence of all signs of any rational being holding an analogous relation to former states of the animate world, affords one, and the only reasonable argument, in support of the hypothesis of a progressive scheme, but none whatever in favour of the fanciéd evolution of one species out of another.

Theory of the gradation in Intellect as shown by the facial angle.—When the celebrated anatomist, Camper, first attempted to estimate the degrees of sagacity of different animals, and of the races of man, by the measurement of the facial angle, some speculators were bold enough to affirm, that certain simiæ differed as little from the more savage races of men, as do these from the human race in general; and that a scale might be traced from 'apes with foreheads villanous low,' to the African variety of the human species, and from that to the European. The facial angle was measured by drawing a line from the prominent centre of the forehead to the most advanced part of the lower jaw-bone, and observing the angle which it made with the horizontal line; and it was affirmed, that there was a regular series from birds to the mammalia.

The gradation from the dog to the monkey was said to be perfect, and from that again to man. One of the ape tribe has a facial angle of 42°, and another, which approximated nearest to man in figure, an angle of 50°. To this succeeds (longo sed proximus intervallo) the head of the African negro, which, as well as that of the Kalmuc, forms an angle of 70°, while that of the European contains 80°. The Roman painters preferred the angle of 95°, and the character of beauty and sublimity, so striking in some works of Grecian sculpture, as in the head of Apollo, and in the Medusa of Sisocles, is given by an angle which amounts to 100° *.

A great number of valuable facts and curious analogies in comparative anatomy, were brought to light during the investigations which were made by Camper, John Hunter and

* Prichard's Phys. Hist. of Mankind, vol. i. p. 159.

others, to illustrate this scale of organization; and their facts and generalizations must not be confounded with the fanciful systems which White and others deduced from them *.

That there is some connexion between an elevated and capacious forehead in certain races of men, and a large development of the intellectual faculties, seems highly probable; and that a low facial angle is frequently accompanied with inferiority of mental powers, is certain; but the attempt to trace a graduated scale of intelligence through the different species of animals accompanying the modifications of the form of the skull, is a mere visionary speculation. It has been found necessary to exaggerate the sagacity of the ape tribe at the expense of the dog, and strange contradictions have arisen in the conclusions deduced from the structure of the elephant, some anatomists being disposed to deny the quadruped the intelligence which he really possesses, because they found that the volume of his brain was small in comparison to that of the other mammalia, while others were inclined to magnify extravagantly the superiority of its intellect, because the vertical height of its skull is so great when compared to its horizontal length.

Different races of men belong all to one species.—It would be irrelevant to our subject if we were to enter into a farther discussion on these topics, because, even if a graduated scale of organization and intelligence could have been established, it would prove nothing in favour of a tendency, in each species, to attain a higher state of perfection. We may refer the reader to the writings of Blumenbach, Prichard, Lawrence, and others, for convincing proofs that the varieties of form, colour, and organization of different races of men, are perfectly consistent with the generally received opinion, that all the individuals of the species have originated from a single pair; and while they exhibit in man as many diversities of a physiological nature, as appear in any other species, they confirm also the opinion of the slight deviation from a common standard of which a species is capable.

* Ch. White on the regular Gradation in Man, &c., 1799.

The power of existing and multiplying in every latitude, and in every variety of situation and climate, which has enabled the great human family to extend itself over the habitable globe, is partly, says Lawrence, the result of physical constitution, and partly of the mental prerogative of man. If he did not possess the most enduring and flexible corporeal frame, his arts would not enable him to be the inhabitant of all climates, and to brave the extremes of heat and cold, and the other destructive influences of local situation *. Yet, notwithstanding this flexibility of bodily frame, we find no signs of indefinite departure from a common standard, and the intermarriages of individuals of the most remote varieties are not less fruitful than between those of the same tribe.

Tiedemann on the brain of the fœtus in vertebrated animals.—There is yet another department of anatomical discovery, to which we must not omit some allusion, because it has appeared to some persons to afford a distant analogy, at least, to that progressive development by which some of the inferior species may have been gradually perfected into those of more complex organization. Tiedemann found, and his discoveries have been most fully confirmed and elucidated by M. Serres, that the brain of the fœtus, in the highest class of vertebrated animals, assumes, in succession, the various forms which belong to fishes, reptiles, and birds, before it acquires those additions and modifications which are peculiar to the mammiferous tribe. So that in the passage from the embryo to the perfect mammifer, there is a typical representation, as it were, of all those transformations which the primitive species are supposed to have undergone, during a long series of generations, between the present period and the remotest geological era.

If you examine the brain of the mammalia, says M. Serres, at an early stage of uterine life, you perceive the cerebral hemispheres consolidated, as in fish, in two vesicles isolated one from the other; at a later period, you see them affect the configuration of the cerebral hemispheres of reptiles; still later again,

* Lawrence, Lectures on Phys. Zool. and Nat. Hist. of Man, p. 192. Ed. 1823.

they present you with the forms of those of birds; finally, they acquire, at the era of birth, and sometimes later, the permanent forms which the adult mammalia present.

The cerebral hemispheres, then, only arrive at the state which we observe in the higher animals by a series of successive metamorphoses. If we reduce the whole of these evolutions to four periods, we shall see that in the first are born the cerebral lobes of fishes, and this takes place homogeneously in all classes. The second period will give us the organization of reptiles; the third the brain of birds; and the fourth the complex hemispheres of mammalia.

If we could develop the different parts of the brain of the inferior classes, we should make in succession a reptile out of a fish, a bird out of a reptile, and a mammiferous quadruped out of a bird. If, on the contrary, we could starve this organ in the mammalia, we might reduce it successively to the condition of the brain of the three inferior classes.

Nature often presents us with this last phenomenon in monsters, but never exhibits the first. Among the various deformities which organized beings may experience, they never pass the limits of their own classes to put on the forms of the class above them. Never does a fish elevate itself so as to assume the form of the brain of a reptile; nor does the latter ever attain that of birds; nor the bird that of the mammifer. It may happen that a monster may have two heads, but the conformation of the brain always remains circumscribed narrowly within the limits of its class *.

Bearing of these discoveries on the theory of progressive development.—It will be observed, that these curious phenomena disclose, in a highly interesting manner, the unity of plan that runs through the organization of the whole series of vertebrated animals; but they lend no support whatever to the notion of a gradual transmutation of one species into another, least of all of the passage, in the course of many generations,

* E. R. A. Serres, Anatomie Comparée du Cerveau, illustrated by numerous plates, tome i., 1824.

from an animal of a more simple, to one of a more complex structure. On the contrary, were it not for the sterility imposed on monsters, as well as on hybrids in general, the argument to be derived from Tiedemann's discovery, like that deducible from experiments respecting hybridity, would be in favour of the successive *degeneracy*, rather than the perfectibility, in the course of ages, of certain classes of organic beings.

Recapitulation.—For the reasons, therefore, detailed in this and the two preceding chapters, we draw the following inferences, in regard to the reality of *species* in nature.

First, That there is a capacity in all species to accommodate themselves, to a certain extent, to a change of external circumstances, this extent varying greatly according to the species.

2dly. When the change of situation which they can endure is great, it is usually attended by some modifications of the form, colour, size, structure, or other particulars; but the mutations thus superinduced are governed by constant laws, and the capability of so varying forms part of the permanent specific character.

3dly. Some acquired peculiarities of form, structure, and instinct, are transmissible to the offspring; but these consist of such qualities and attributes only as are intimately related to the natural wants and propensities of the species.

4thly. The entire variation from the original type, which any given kind of change can produce, may usually be effected in a brief period of time, after which no farther deviation can be obtained by continuing to alter the circumstances, though ever so gradually,—indefinite divergence, either in the way of improvement or deterioration, being prevented, and the least possible excess beyond the defined limits being fatal to the existence of the individual.

5thly. The intermixture of distinct species is guarded against by the aversion of the individuals composing them to sexual union, or by the sterility of the mule offspring. It does not

appear that true hybrid races have ever been perpetuated for several generations, even by the assistance of man; for the cases usually cited relate to the crossing of mules with individuals of pure species, and not to the intermixture of hybrid with hybrid.

6thly. From the above considerations, it appears that species have a real existence in nature, and that each was endowed, at the time of its creation, with the attributes and organization by which it is now distinguished.

CHAPTER V.

Laws which regulate the geographical distribution of species—Analogy of climate not attended with identity of species—Botanical geography—Stations—Habitations—Distinct provinces of indigenous plants—Vegetation of islands—Marine vegetation—In what manner plants become diffused—Effects of wind, rivers, marine currents—Agency of animals—Many seeds pass through the stomachs of animals and birds undigested—Agency of man in the dispersion of plants, both voluntary and involuntary—Its analogy to that of the inferior animals.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES.

NEXT to determining the question whether species have a real existence, the consideration of the laws which regulate their geographical distribution is a subject of primary importance to the geologist. It is only by studying these laws with attention, by observing the position which groups of species occupy at present, and inquiring how these may be varied in the course of time by migrations, by changes in physical geography, and other causes, that we can hope to learn whether the duration of species be limited, or in what manner the state of the animate world is affected by the endless vicissitudes of the inanimate.

Different regions inhabited by distinct species.—That different regions of the globe are inhabited by entirely distinct animals and plants is a fact which has been familiar to all naturalists since Buffon first pointed out the want of *specific* identity between the land quadrupeds of America and those of the Old World. The same phenomenon has, in later times, been forced, in a striking manner, upon our attention, by the examination of New Holland, where the indigenous species of animals and plants were found to be, almost without exception, distinct from those known in other parts of the world.

But the extent of this parcelling out of the globe amongst different *nations*, as they have been termed, of plants and ani-

mals,—the universality of a phenomenon so extraordinary and unexpected, may be considered as one of the most interesting facts clearly established by the advance of modern science.

Scarcely fourteen hundred species of plants appear to have been known and described by the Greeks, Romans, and Arabians. At present, more than three thousand species are enumerated, as natives of our own island *. In other parts of the world there have been collected, perhaps, upwards of seventy thousand species. It was not to be supposed, therefore, that the ancients should have acquired any correct notions respecting what may be called the geography of plants, although the influence of climate on the character of the vegetation could hardly have escaped their observation.

Analogy of climate not attended with identity of species.—Antecedently to investigation, there was no reason for presuming that the vegetable productions, growing wild in the eastern hemisphere, should be unlike those of the western, in the same latitude; nor that the plants of the Cape of Good Hope should be unlike those of the South of Europe; situations where the climate is little dissimilar. The contrary supposition would have seemed more probable, and we might have anticipated an almost perfect identity in the animals and plants which inhabit corresponding parallels of latitude. The discovery, therefore, that each separate region of the globe, both of the land and water, is occupied by distinct groups of species, and that most of the exceptions to this general rule may be referred to disseminating causes now in operation, is eminently calculated to excite curiosity, and to stimulate us to seek some hypothesis respecting the first introduction of species which may be reconcileable with such phenomena.

BOTANICAL GEOGRAPHY.

A comparison of the *plants* of different regions of the globe affords results more to be depended upon in the present state of our knowledge than those relating to the animal kingdom,

* Barton's Lectures on the Geography of Plants, p. 2.

because the science of botany is more advanced, and probably comprehends a great proportion of the total number of the vegetable productions of the whole earth.

Humboldt.—Humboldt, in several eloquent passages of his Personal Narrative, was among the first to promulgate philosophical views on this subject. Every hemisphere, says this traveller, produces plants of different species; and it is not by the diversity of climates that we can attempt to explain why equinoctial Africa has no laurinIæ, and the New World no heaths; why the calceolariæ are found only in the southern hemisphere; why the birds of the continent of India glow with colours less splendid than the birds of the hot parts of America; finally, why the tiger is peculiar to Asia, and the ornithorhynchus to New Holland *.

'We can conceive,' he adds, 'that a small number of the families of plants, for instance the musaceæ and the palms, cannot belong to very cold regions, on account of their internal structure and the importance of certain organs; but we cannot explain why no one of the family of melastomas vegetates north of the parallel of thirty degrees; or why no rose-tree belongs to the southern hemisphere. Analogy of climates is often found in the two continents without identity of productions †.'

De Candolle.—The luminous essay of De Candolle on 'Botanical Geography' presents us with the fruits of his own researches and those of Humboldt, Brown, and other eminent botanists, so arranged, that the principal phenomena of the distribution of plants are exhibited in connexion with the causes to which they are chiefly referrible ‡. 'It might not, perhaps, be difficult,' observes this writer, 'to find two points, in the United States and in Europe, or in equinoctial America and Africa, which present all the same circumstances: as for example, the same temperature, the same height above the sea,

* Pers. Nar. vol. v. p. 180. † Ibid.

‡ Essai Elémentaire de Géographie Botanique. Extrait du 18e vol. du Dict. des Sci. Nat.

a similar soil, an equal dose of humidity, yet nearly all, *perhaps all*, the plants in these two similar localities shall be distinct. A certain degree of analogy, indeed, of aspect, and even of structure, might very possibly be discoverable between the plants of the two localities in question, but the *species* would in general be different. Circumstances, therefore, different from those which now determine the *stations*, have had an influence on the *habitations* of plants.'

Stations and habitations of plants.—As we shall frequently have occasion to speak of the *stations* and *habitations* of plants in the technical sense in which the terms are used in the above passage, we may remind the geological reader that station indicates the peculiar nature of the locality where each species is accustomed to grow, and has reference to climate, soil, humidity, light, elevation above the sea, and other analogous circumstances; whereas by habitation is meant a general indication of the country where a plant grows wild. Thus the *station* of a plant may be a salt-marsh, in a temperate climate, a hill-side, the bed of the sea, or a stagnant pool. Its *habitation* may be Europe, North America, or New Holland between the tropics. The study of stations has been styled the topography, that of habitations the geography of botany. The terms thus defined, express each a distinct class of ideas, which have been often confounded together, and which are equally applicable in zoology.

Distinct provinces of indigenous plants.—In further illustration of the principle above alluded to, that difference of longitude, independently of any influence of temperature, is accompanied by a great, and sometimes a complete diversity in the species of plants, De Candolle observes, that out of 2891 species of phanerogamic plants described by Pursh, in the United States, there are only 385 which are found in northern or temperate Europe. MM. Humboldt and Bonpland, in all their travels through equinoctial America, found only twenty-four species (these being all cyperacea and graminea) common

to America and any part of the Old World. On comparing New Holland with Europe, Mr. Brown ascertained that out of 4100 species, discovered in Australia, there were only 166 common to Europe, and of this small number there were some few which may have been transported thither by man.

But it is still more remarkable, that in the more widely-separated parts of the ancient continent, notwithstanding the existence of an uninterrupted land-communication, the diversity in the specific character of the respective vegetations is almost as striking. Thus there is found one assemblage of species in China, another in the countries bordering the Black Sea and the Caspian, a third in those surrounding the Mediterranean, a fourth in the great platforms of Siberia and Tartary, and so forth.

The distinctness of the groups of indigenous plants, in the same parallel of latitude, is greatest where continents are disjoined by a wide expanse of ocean. In the northern hemisphere, near the Pole, where the extremities of Europe, Asia, and America unite or approach near to one another, a considerable number of the same species of plants are found, common to the three continents. But it has been remarked, that these plants, which are thus so widely diffused in the Arctic regions, are also found in the chain of the Aleutian islands, which stretch almost across from America to Asia, and which may probably have served as the channel of communication for the partial blending of the Floras of the adjoining regions. It has, indeed, been found to be a general rule, that plants found at two points very remote from each other, occur also in places intermediate.

Vegetation of islands.—In islands very distant from continents the total number of plants is comparatively small; but a large proportion of the species are such as occur nowhere else. In so far as the Flora of such islands is not peculiar to them, it contains, in general, species common to the nearest main lands *.

* Prichard, vol. i. p. 36. Brown, Appendix to Flinders.

The islands of the great southern ocean exemplify these rules; the easternmost containing more American, and the western more Indian plants *. Madeira and Teneriffe contain many species, and even entire genera, peculiar to them; but they have also plants in common with Portugal, Spain, the Azores, and the north-west coast of Africa †.

In the Canaries, out of 533 species of phanerogamous plants, it is said that 310 are peculiar to these isles, and the rest identical with those of the African continent; but in the Flora of St. Helena, which is so far distant even from the western shores of Africa, there have been found, out of sixty-one native species, only *two or three* which are to be found in any other part of the globe.

Number of botanical provinces.—De Candolle has enumerated twenty great botanical provinces inhabited by indigenous or aboriginal plants; and although many of these contain a variety of species which are common to several others, and sometimes to places very remote, yet the lines of demarcation are, upon the whole, astonishingly well defined ‡. Nor is it likely that the bearing of the evidence on which these general views are founded will ever be materially affected, since they are already confirmed by the examination of seventy or eighty thousand species of plants.

The entire change of opinion which the contemplation of these phenomena has brought about is worthy of remark. The first travellers were persuaded that they should find, in distant regions, the plants of their own country, and they took a pleasure in giving them the same names. It was some time before this illusion was dissipated; but so fully sensible did botanists at last become of the extreme smallness of the number of phænogamous plants common to different continents, that the

* Forster, Observations, &c.

† Humboldt, Pers. Nar., vol. i. p. 270 of the translation. Prichard, Phys. Hist. of Mankind, vol. i. p. 37.

‡ See a farther subdivision by which twenty-seven provinces are made, by M. Alph. De Candolle, son of De Candolle. Monogr. des Campanulées. Paris, 1830.

ancient Floras fell into disrepute. All grew diffident of the pretended identifications, and we now find that every naturalist is inclined to examine each supposed exception with scrupulous severity *. If they admit the fact, they begin to speculate on the mode whereby the seeds may have been transported from one country into the other, or inquire on which of two continents the plant was indigenous, assuming that a species, like an individual, cannot have two birth-places.

Marine Vegetation.—The marine vegetation is less known, but we learn from Lamouroux, that it is divisible into different systems, apparently as distinct as those on the land, notwithstanding that the uniformity of temperature is so much greater in the ocean. For on that ground we might have expected the phenomenon of partial distribution to have been far less striking, since climate is, in general, so influential a cause in checking the dispersion of species from one zone to another.

Stations of marine plants.—The number of hydrophytes, as they are termed, is very considerable, and their stations are found to be infinitely more varied than could have been anticipated; for while some plants are covered and uncovered daily by the tide, others live in abysses of the ocean, at the extraordinary depth of one thousand feet; and although in such situations there must reign darkness more profound than night, at least to our organs, many of these vegetables are highly coloured. From the analogy of terrestrial plants we should have inferred that the colouring of the algæ was derived from the influence of the solar rays; yet we are compelled to doubt when we reflect how feeble must be the rays which penetrate to these great depths.

The subaqueous vegetation of the Mediterranean is, upon the whole, distinct from that of the Atlantic on the west, and that part of the Arabian gulf which is immediately contiguous on the south. Other botanical provinces are found in the West-Indian seas, including the gulf of Mexico; in the ocean which washes the shores of South America, in the Indian ocean

* De Candolle, Essai Elémen. de Géog. Botan., p. 45.

and its gulfs, in the seas of Australia, and in the Atlantic basin, from the 40° of north latitude to the pole. There are very few species common to the coast of Europe and the United States of North America, and none common to the Straits of Magellan and the shores of Van Diemen's Land.

It must not be overlooked, that the distinctness alluded to between the vegetation of these several countries relates strictly to *species* and not to forms. In regard to the numerical preponderance of certain forms, and many peculiarities of internal structure, there is a marked agreement in the vegetable productions of districts placed in corresponding latitudes, and under similar physical circumstances, however remote their position. Thus there are innumerable points of analogy between the vegetation of the Brazils, equinoctial Africa, and India; and there are also points of difference wherein the plants of these regions are distinguishable from all extra-tropical groups. But there are very few species common to the three continents. The same may be said, if we compare the plants of the Straits of Magellan with those of Van Diemen's Land, or the vegetation of the United States with that of the middle of Europe: the species are distinct, but the forms are in a great degree analogous.

Let us now consider what means of diffusion, independently of the agency of man, are possessed by plants, whereby, in the course of ages, they may be enabled to stray from one of the botanical provinces above mentioned to another, and to establish new colonies at a great distance from their birth-place.

Manner in which plants become diffused.—The principal of the inanimate agents provided by nature for scattering the seeds of plants over the globe, are the movements of the atmosphere and of the ocean, and the constant flow of water from the mountains to the sea. To begin with the winds: a great number of seeds are furnished with downy and feathery appendages, enabling them, when ripe, to float in the air, and to be wafted easily to great distances by the most gentle breeze. Other plants are fitted for dispersion by means of an attached

wing, as in the case of the fir-tree, so that they are caught up by the wind as they fall from the cone, and are carried to a distance. Amongst the comparatively small number of plants known to Linnæus, no less than one hundred and thirty-eight genera are enumerated as having winged seeds.

Agency of the winds.—As winds often prevail for days, weeks, or even months together, in the same direction, these means of transportation may sometimes be without limits; and even the heavier grains may be borne through considerable spaces, in a very short time, during ordinary tempests; for strong gales, which can sweep along grains of sand, often move at the rate of about forty miles an hour, and if the storm be very violent, at the rate of fifty-six miles *. The hurricanes of tropical regions, which root up trees and throw down buildings, sweep along at the rate of ninety miles an hour, so that, for however short a time they prevail, they may carry even the heavier fruits and seeds over friths and seas of considerable width, and, doubtless, are often the means of introducing into islands the vegetation of adjoining continents. Whirlwinds are also instrumental in bearing along heavy vegetable substances to considerable distances. Slight ones may frequently be observed in our fields, in summer, carrying up haycocks into the air, and then letting fall small tufts of hay far and wide over the country; but they are sometimes so powerful as to dry up lakes and ponds, and to break off the boughs of trees, and carry them up in a whirling column of air.

Franklin tells us, in one of his letters, that he saw in Maryland, a whirlwind which began by taking up the dust which lay in the road, in the form of a sugar-loaf with the pointed end downwards, and soon after grew to the height of forty or fifty feet, being twenty or thirty in diameter. It advanced in a direction contrary to the wind, and although the rotatory motion of the column was surprisingly rapid, its onward progress was sufficiently slow to allow a man to keep pace with it on foot. Franklin followed it on horseback,

* Annuaire du Bureau des Longitudes.

accompanied by his son, for three-quarters of a mile, and saw it enter a wood, were it twisted and turned round large trees with surprising force. These were carried up in a spiral line, and were seen flying in the air, together with boughs and innumerable leaves, which, from their height, appeared reduced to the apparent size of flies. As this cause operates at different intervals of time throughout a great portion of the earth's surface, it may be the means of bearing not only plants but insects, land-testacea and their eggs, with many other species of animals, to points which they could never otherwise have reached, and from which they may then begin to propagate themselves again as from a new centre.

Distribution of Cryptogamous plants.—It has been found that a great numerical proportion of the exceptions to the limitation of species to certain quarters of the globe, occur in the various tribes of cryptogamic plants. Linnæus observed, that as the germs of plants of this class, such as mosses, fungi, and lichens, consist of an impalpable powder, the particles of which are scarcely visible to the naked eye, there is no difficulty to account for their being dispersed throughout the atmosphere, and carried to every point of the globe, where there is a station fitted for them. Lichens in particular ascend to great elevations, sometimes growing two thousand feet above the line of perpetual snow, at the utmost limits of vegetation, and where the mean temperature is nearly at the freezing point. This elevated position must contribute greatly to facilitate the dispersion of those buoyant particles of which their fructification consists *.

Some have inferred, from the springing up of mushrooms whenever particular soils and decomposed organic matter are mixed together, that the production of fungi is accidental, and not analogous to that of perfect plants †. But Fries, whose authority on these questions is entitled to the highest respect, has shown the fallacy of this argument in favour of the old

* Linn., Tour in Lapland, vol. ii. p. 282.

† Lindley, Introd. to Nat. Syst. of Botany, who cites Fries.

doctrine of equivocal generation. 'The sporules of fungi,' says this naturalist, 'are so infinite, that in a single individual of Reticularia maxima, I have counted above ten millions, and so subtile as to be scarcely visible, often resembling thin smoke; so light that they may be raised perhaps by evaporation into the atmosphere, and dispersed in so many ways by the attraction of the sun, by insects, wind, elasticity, adhesion, &c., that it is difficult to conceive a place from which they may be excluded.'

Agency of rivers and currents.—In turning our attention, in the next place, to the instrumentality of the aqueous agents of dispersion, we cannot do better than cite the words of one of our ablest botanical writers. 'The mountain-stream or torrent,' observes Keith, 'washes down to the valley the seeds which may accidentally fall into it, or which it may happen to sweep from its banks when it suddenly overflows them. The broad and majestic river, winding along the extensive plain, and traversing the continents of the world, conveys to the distance of many hundreds of miles the seeds that may have vegetated at its source. Thus the southern shores of the Baltic are visited by seeds which grew in the interior of Germany; and the western shores of the Atlantic by seeds that have been generated in the interior of America *.' Fruits, moreover, indigenous to America and the West Indies, such as that of the Mimosa scandens, the cashew-nut, and others, have been known to be drifted across the Atlantic by the Gulf stream, on the western coasts of Europe, in such a state that they might have vegetated had the climate and soil been favourable. Among these the Guilandina Bonduc, a leguminous plant, is particularly mentioned, as having been raised from a seed found on the west coast of Ireland †.

Sir Hans Sloane states that several kinds of beans cast ashore on the Orkney Isles and the coast of Ireland, are derived from trees which grow in the West Indies, and many of

* System of Physiological Botany, vol. ii. p. 405.

† Brown, Append. to Tuckey, No. V. p. 481.

them in Jamaica. He conjectures that they may have been conveyed by rivers into the sea, and then by the Gulf stream to greater distances, in the same manner as the sea-weed called Lenticula marina, or Sargasso, which grows on the rocks about Jamaica, is known to be 'carried by the winds and current towards the coast of Florida, and thence into the North American ocean, where it lies very thick on the surface of the sea *.'

The absence of liquid matter in the composition of seeds renders them comparatively insensible to heat and cold, so that they may be carried without detriment through climates where the plants themselves would instantly perish. Such is their power of resisting the effects of heat, that Spallanzani mentions some seeds that germinated after having been boiled in water †. When, therefore, a strong gale, after blowing violently off the land for a time, dies away, and the seeds alight upon the surface of the waters, or wherever the ocean, by eating away the sea-cliffs, throws down into its waves plants which would never otherwise approach the shores, the tides and currents become active instruments in assisting the dissemination of almost all classes of the vegetable kingdom.

In a collection of six hundred plants from the neighbourhood of the river Zaire, in Africa, Mr. Brown found that thirteen species were also met with on the opposite shores of Guiana and Brazil. He remarked that most of these plants were only found on the lower parts of the river Zaire, and were chiefly such as produced seeds capable of retaining their vitality a long time in the currents of the ocean.

The migration of plants aided by islands.—Islands, moreover, and even the smallest rocks, play an important part in aiding such migrations, for when seeds alight upon them from the atmosphere, or are thrown up by the surf, they often vegetate and supply the winds and waves with a repetition of new and uninjured crops of fruits and seeds, which may afterwards pursue their course through the atmosphere, or

* Phil. Trans. 1696. † System of Physiological Botany, vol. ii. p. 403.

along the surface of the sea, in the same direction. The number of plants found at any given time on an islet affords no test whatever of the extent to which it may have co-operated towards this end, since a variety of species may first thrive there and then perish, and be followed by other chance-comers like themselves.

Currents and winds in the arctic regions drift along icebergs covered with an alluvial soil on which herbs and pine-saplings are seen growing, which often continue to vegetate on some distant shore where the ice-island is stranded.

Dispersion of marine plants.—With respect to marine vegetation, the seeds being in their native element, may remain immersed in water without injury for indefinite periods, so that there is no difficulty in conceiving the diffusion of species wherever uncongenial climates, contrary currents, and other causes, do not interfere. All are familiar with the sight of the floating sea-weed

> 'Flung from the rock on ocean's foam to sail,
> Where'er the surge may sweep, the tempest's breath prevail.'

Remarkable accumulations of that species of sea-weed generally known as gulf-weed, or sargasso, occur on each side of the equator in the Atlantic, Pacific, and Indian Oceans. Columbus and other navigators, who first encountered these banks of algæ in the Northern Atlantic, compared them to vast inundated meadows, and state that they retarded the progress of their vessels. The most extensive bank is a little west of the meridian of Fayal, one of the Azores, between latitude 35° and 36°; violent north winds sometimes prevail in this space, and drive the sea-weed to low latitudes, as far as the 24th or even the 20th degree *.

The hollow pod-like receptacles in which the seeds of many algæ are lodged, and the filaments attached to the seed-vessels of others, seem intended to give buoyancy, and we may observe that these hydrophytes are in general *proliferous*, so that the smallest fragment of a branch can be developed into a perfect

* Greville, Introduction to Algæ Britannicæ, p. 12.

plant. The seeds, moreover, of the greater number of species are enveloped with a mucous matter like that which surrounds the eggs of some fish, and which not only protects them from injury, but serves to attach them to floating bodies or to rocks.

Agency of animals in the distribution of plants.—But we have as yet considered part only of the fertile resources of nature for conveying seeds to a distance from their place of growth. The various tribes of animals are busily engaged in furthering an object whence they derive such important advantages. Sometimes an express provision is found in the structure of seeds to enable them to adhere firmly by prickles, hooks, and hairs, to the coats of animals, or feathers of the winged tribe, to which they remain attached for weeks, or even months, and are borne along into every region whither birds or quadrupeds may migrate. Linnæus enumerates fifty genera of plants, and the number now known to botanists is much greater, which are armed with hooks, by which, when ripe, they adhere to the coats of animals. Most of these vegetables, he remarks, require a soil enriched with dung. Few have failed to mark the locks of wool hanging on the thorn-bushes, wherever the sheep pass, and it is probable that the wolf or lion never give chace to herbivorous animals without being unconsciously subservient to this part of the vegetable economy.

A deer has strayed from the herd when browsing on some rich pasture, when he is suddenly alarmed by the approach of his foe. He instantly plunges through many a thicket, and swims through many a river and lake. The seeds of the herbs and shrubs adhere to his smoking flanks, and are washed off again by the streams. The thorny spray is torn off and fixes itself in his hairy coat, until brushed off again in other thickets and copses. Even on the spot where the victim is devoured, many of the seeds which he had swallowed immediately before the pursuit may be left on the ground uninjured.

The passage, indeed, of undigested seeds through the stomachs of animals is one of the most efficient causes of the dissemination of plants, and is of all others, perhaps, the most

likely to be overlooked. Few are ignorant that a portion of the oats eaten by a horse preserve their germinating faculty in the dung. The fact of their being still nutritious is not lost on the sagacious rook. To many, says Linnæus, it seems extraordinary, and something of a prodigy, that when a field is well tilled and sown with the best wheat, it frequently produces darnel or the wild oat, especially if it be manured with new dung: they do not consider that the fertility of the smaller seeds is not destroyed in the stomachs of animals *.

Agency of Birds.—Some birds of the order Passeres† devour the seeds of plants in great quantities, which they eject again in very distant places, without destroying its faculty of vegetation; thus a flight of larks will fill the cleanest field with a great quantity of various kinds of plants, as the melilot trefoil (*Medicago lupulina*), and others whose seeds are so heavy that the wind is not able to scatter them to any distance. In like manner, the blackbird and missel-thrush, when they devour berries in too great quantities, are known to consign them to the earth undigested in their excrement ‡.

Pulpy fruits serve quadrupeds and birds as food, while their seeds, often hard and indigestible, pass uninjured through the intestines, and are deposited far from their original place of growth in a condition peculiarly fit for vegetation §. So well are our farmers, in some parts of England, aware of this fact, that when they desire to raise a quick-set hedge in the shortest possible time, they feed turkeys with the haws of the common white-thorn (*Cratægus oxyacantha*), and then sow the stones which are ejected in their excrement, whereby they gain an entire year in the growth of the plant ||. Birds when they pluck cherries, sloes, and haws, fly away with them to

* Linnæus, Amœn. Acad., vol. ii. p. 409.

† Amœn. Acad., vol. iv., Essay 75, § 8.

‡ Ibid. vol. vi. § 22.

§ Smith's Introd. to Phys. and Syst. Botany, p. 304, 1807.

|| This information was communicated to me by Professor Henslow, of Cambridge.

some convenient place, and when they have devoured the fruit drop the stone into the ground. Captain Cook, in his account of the volcanic island of Tanna, one of the New Hebrides, which he visited in his second voyage, makes the following interesting observation. 'Mr. Forster, in his botanical excursion this day, shot a pigeon, in the craw of which was a wild nutmeg. He took some pains to find the tree on this island, but his endeavours were without success*.' It is easy, therefore, to perceive, that birds in their migrations to great distances, and even across seas, may transport seeds to new isles and continents.

The sudden deaths to which great numbers of frugivorous birds are annually exposed, must not be omitted as auxiliary to the transportation of seeds to new habitations. When the sea retires from the shore, and leaves fruits and seeds on the beach, or in the mud of estuaries, it might, by the returning tide, wash them away again, or destroy them by long immersion; but when they are gathered by land birds which frequent the sea-side, or by waders and water-fowl, they are often borne inland, and if the bird to whose crop they have been consigned is killed, they may be left to grow up far from the sea. Let such an accident happen but once in a century, or a thousand years, it will be sufficient to spread many of the plants from one continent to another; for, in estimating the activity of these causes, we must not consider whether they act slowly in relation to the period of our observation, but in reference to the duration of species in general.

Let us trace the operation of this cause in connexion with others. A tempestuous wind bears the seeds of a plant many miles through the air, and then delivers them to the ocean; the oceanic current drifts them to a distant continent; by the fall of the tide they become the food of numerous birds, and one of these is seized by a hawk or eagle, which, soaring across hill and dale to a place of retreat, leaves, after devouring its prey, the unpalatable seeds to spring up and flourish in a new soil.

* Book iii., ch. iv.

The machinery before adverted to is so capable of disseminating seeds over almost unbounded spaces, that were we more intimately acquainted with the economy of nature we might probably explain all the instances which occur of the aberration of plants to great distances from their native countries. The real difficulty which must present itself to every one who contemplates the present geographical distribution of species, is the small number of exceptions to the rule of the non-intermixture of different groups of plants. Why have they not, supposing them to have been ever so distinct originally, become more blended and confounded together in the lapse of ages?

Agency of man in the dispersion of plants.—But in addition to all the agents already enumerated as instrumental in diffusing plants over the globe, we have still to consider man—one of the most important of all. He transports with him, into every region, the vegetables which he cultivates for his wants, and is the involuntary means of spreading a still greater number which are useless to him, or even noxious. 'When the introduction of cultivated plants is of recent date, there is no difficulty in tracing their origin; but when it is of high antiquity, we are often ignorant of the true country of the plants on which we feed. No one contests the American origin of the maize or the potato, nor the origin, in the old world, of the coffee-tree and of wheat. But there are certain objects of culture, of very ancient date, between the tropics, such, for example, as the banana, of which the origin cannot be verified. Armies, in modern times, have been known to carry, in all directions, grain and cultivated vegetables from one extremity of Europe to the other, and thus have shown us how, in more ancient times, the conquests of Alexander, the distant expeditions of the Romans, and afterwards the Crusades, may have transported many plants from one part of the world to the other *.'

But besides the plants used in agriculture, the number which

* De Candolle, Essai Elémen. &c. p. 50.

have been naturalized by accident, or which man has spread unintentionally, is considerable. One of our old authors, Josselyn, gives a catalogue of such plants as had, in his time, sprung up in the colony since the English planted and kept cattle in New England. They were two and twenty in number. The common nettle was the first which the settlers noticed, and the plantain was called by the Indians, 'English man's foot,' as if it sprung from their footsteps *.

'We have introduced everywhere,' observes De Candolle, 'some weeds which grow among our various kinds of wheat, and which have been received, perhaps, originally from Asia with them. Thus, together with the Barbary wheat, the inhabitants of the south of Europe have sown, for many ages, the plants of Algiers and Tunis. With the wools and cottons of the East, or of Barbary, there are often brought into France the grains of exotic plants, some of which naturalize themselves. Of this I will cite a striking example. There is, at the gate of Montpellier, a meadow set apart for drying foreign wool *after it has been washed*. There hardly passes a year without foreign plants being found naturalized in this drying-ground. I have gathered there Centaurea parviflora, Psoralea palæstina, and Hypericum crispum.' This fact is not only illustrative of the aid which man lends inadvertently to the propagation of plants, but it also demonstrates the multiplicity of seeds which are borne about in the woolly and hairy coats of wild animals.

The same botanist mentions instances of plants naturalized in sea-ports by the ballast of ships, and several examples of others which have spread through Europe from botanical gardens, so as to have become more common than many indigenous species.

It is scarcely a century, says Linnæus †, since the Canadian erigiron, or flea-bane, was brought from America to the botanical garden at Paris, and already the seeds have been carried

* Quarterly Review, vol. xxx. p. 8.

† Essay on the Habitable Earth, Amœn. Acad., vol. ii. p. 409.

by the winds, so that it is diffused over France, the British islands, Italy, Sicily, Holland, and Germany. Several others are mentioned by the Swedish naturalist, as having been dispersed by similar means. The common thorn-apple, *Datura stramonium,* observes Willdenow, now grows as a noxious weed throughout all Europe, with the exception of Sweden, Lapland, and Russia. It came from the East Indies and Abyssinia to us, and was so universally spread by certain quacks who used its seed as an emetic *.

In hot and ill-cultivated countries, such naturalizations take place more easily. Thus the Chenopodium ambrosioides, sown by Mr. Burchell on a point of St. Helena, multiplied so in four years as to become one of the commonest weeds in the island †.

The most remarkable proof, says De Candolle, of the extent to which man is unconsciously the instrument of dispersing and naturalizing species, is found in the fact, that in New Holland, America and the Cape of Good Hope, the aboriginal European species exceed in number all the others which have come from any distant regions, so that, in this instance, the influence of man has surpassed that of all the other causes which tend to disseminate plants to remote districts.

Although we are but slightly acquainted, as yet, with the extent of our instrumentality in naturalizing species, yet the facts ascertained afford no small reason to suspect that the number which we introduce unintentionally, exceeds all those transported by design. Nor is it unnatural to suppose that the functions, which the inferior beings extirpated by man once discharged in the economy of nature, should devolve upon the human race. If we drive many birds of passage from different countries, we are probably required to fulfil their office of carrying seeds, eggs of fish, insects, molluscs, and other creatures, to distant regions; if we destroy quadrupeds, we must replace them, not merely as consumers of the animal and vegetable substances which they devoured, but as disseminators of plants,

* Principles of Botany, p. 389. † Ibid.

and of the inferior classes of the animal kingdom. We do not mean to insinuate that the same changes which man brings about, would have taken place by means of the agency of other species, but merely that he supersedes a certain number of agents, and so far as he disperses plants unintentionally, or against his will, his intervention is strictly analogous to that of the species so extirpated.

We may observe, moreover, that if, at former periods, the animals inhabiting any given district have been partially altered by the extinction of some species, and the introduction of others, whether by new creations or by immigration, a change must have taken place in regard to the particular plants conveyed about with them to foreign countries. As for example, when one set of migratory birds is substituted for another, the countries from and to which seeds are transported are immediately changed. Vicissitudes, therefore, analogous to those which man has occasioned, may have previously attended the springing up of new relations between species in the vegetable and animal worlds.

It may also be remarked, that if man is the most active agent in enlarging, so also is he in circumscribing the geographical boundaries of particular plants. He promotes the migration of some, he retards that of other species, so that while in many respects he appears to be exerting his power to blend and confound the various provinces of indigenous species, he is, in other ways, instrumental in obstructing the fusion into one group of the inhabitants of contiguous provinces.

Thus, for example, when two botanical regions exist in the same great continent, such as *the European region,* comprehending the central parts of Europe and those surrounding the Mediterranean, and *the Oriental region,* as it has been termed, embracing the countries adjoining the Black Sea and the Caspian, the interposition between these of thousands of square miles of cultivated lands, opposes a new and powerful barrier against the mutual interchange of indigenous plants. Botanists are well aware that garden plants naturalize and dif-

fuse themselves with great facility in comparatively unreclaimed countries, but spread themselves slowly and with difficulty in districts highly cultivated. There are many obvious causes for this difference; by drainage and culture the natural variety of stations is diminished, and those stray individuals by which the passage of a species from one fit station to another is effected, are no sooner detected by the agriculturist, than they are uprooted as weeds. The larger shrubs and trees, in particular, can scarcely ever escape observation, when they have attained a certain size, and will rarely fail to be cut down if unprofitable.

The same observations are applicable to the interchange of the insects, birds, and quadrupeds of two regions situated like those above alluded to. No beasts of prey are permitted to make their way across the intervening arable tracts. Many birds and hundreds of insects, which would have found some palatable food amongst the various herbs and trees of the primeval wilderness, are unable to subsist on the olive, the vine, the wheat, and a few trees and grasses favoured by man. In addition therefore, to his direct intervention, man, in this case, operates indirectly to impede the dissemination of plants, by intercepting the migrations of animals, many of which would otherwise have been active in transporting seeds from one province to another.

Whether in the vegetable kingdom the influence of man will tend, after a considerable lapse of ages, to render the geographical range of *species in general* more extended, as De Candolle seems to anticipate, or whether the compensating agency above alluded to will not counterbalance the exceptions caused by our naturalizations, admits at least of some doubt. In the attempt to form an estimate on this subject, we must be careful not to underrate, or almost overlook, as some appear to have done, the influence of man in checking the diffusion of plants, and restricting their distribution to narrower limits.

CHAPTER VI.

Laws which regulate the geographical distribution of species, *continued*—Geographical distribution of animals—Buffon on the specific distinctness of the quadrupeds of the old and new world—Different regions of indigenous mammalia—Quadrupeds in islands—Range of the Cetacea—Dissemination of quadrupeds—their powers of swimming—Migratory instincts—Drifting of quadrupeds on ice-floes—On floating islands of drift-timber—Migrations of Cetacea—Habitations of birds—Their migrations and facilities of diffusion—Distribution of reptiles and their powers of dissemination.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES, *continued.*

Geographical distribution of animals.—ALTHOUGH in speculating on 'philosophical possibilities,' said Buffon, the same temperature might have been expected, all other circumstances being equal, to produce the same beings in different parts of the globe, both in the animal and vegetable kingdoms, yet it is an undoubted fact, that when America was discovered, its indigenous quadrupeds were all dissimilar from those previously known in the old world. The elephant, the rhinoceros, the hippopotamus, the cameleopard, the camel, the dromedary, the buffalo, the horse, the ass, the lion, the tiger, the apes, the baboons, and a number of other mammalia, were nowhere to be met with on the new continent; while in the old, the American species, of the same great class, were nowhere to be seen—the tapir, the lama, the pecari, the jaguar, the couguar, the agouti, the paca, the coati, and the sloth.

These phenomena, although few in number relatively to the whole animate creation, were so striking and so positive in their nature, that the French naturalist caught sight at once of a general law in the geographical distribution of organic beings, namely, the limitation of groups of distinct species to regions separated from the rest of the globe by certain natural barriers. It was, therefore, in a truly philosophical spirit that, relying

on the clearness of the evidence obtained respecting the larger quadrupeds, he ventured to call in question the identifications announced by some contemporary naturalists, of species of animals said to be common to the southern extremities of America and Africa *.

Causes which prevent the migration of animals.—The migration of quadrupeds from one part of the globe to the other, observes one of our ablest writers, is prevented by uncongenial climates and the branches of the ocean which intersect continents. 'Hence by a reference to the geographical site of countries, we may divide the earth into a certain number of regions fitted to become the abodes of particular groups of animals, and we shall find, on inquiry, that each of these provinces, thus conjecturally marked out, is actually inhabited by a distinct nation of quadrupeds †.'

Where the continents of the old and new world approximate to each other towards the north, the narrow straits which separate them are frozen over in winter, and the distance is further lessened by intervening islands. Thus a passage from one continent to another becomes practicable to such quadrupeds as are fitted to endure the intense cold of the arctic circle. Accordingly, the whole arctic region has become one of the provinces of the animal kingdom, and contains many species common to both the great continents. But the temperate regions of America, which are separated by a wide extent of ocean from those of Europe and Asia, contain each a distinct nation of indigenous quadrupeds. There are three groups of *tropical* mammalia belonging severally to America, Africa, and continental India, each inhabiting lands separated from each other by the ocean.

In Peru and Chili, says Humboldt, the region of the grasses,

* Buffon, vol. v.—On the Virginian Opossum.

† Prichard's Phys. Hist. of Mankind, vol. i. p. 54. In some of the preliminary chapters will be found a sketch of the leading facts illustrative of the geographical distribution of animals, drawn up with the author's usual clearness and ability.

which is at an elevation of from twelve thousand three hundred to fifteen thousand four hundred feet, is inhabited by crowds of lama, guanaco, and alpaca. These quadrupeds, which here represent the genus camel of the ancient continent, have not extended themselves either to Brazil or Mexico, because, during their journey, they must necessarily have descended into regions that were too hot for them *.

Animals in New Holland.—New Holland is well known to contain a most singular and characteristic assemblage of mammiferous animals, consisting of more than forty species of the marsupial family, of which scarcely any congeners occur elsewhere, except a few species in some islands of the Indian archipelago and the opossums of America. There are it appears some examples of marsupial animals in the eastern hemisphere out of the Australian continent. Thus the Phalangista vulpina inhabits both Sumatra and New Holland. The P. ursina is found in the island of Celebes; P. chrysorrhos in the Moluccas; P. maculata in Banda and Aboyna; P. cavifrons, ibid †.

This almost exclusive occupation of the Australian continent by the kangaroos and other tribes of pouched animals, although it has justly excited great attention, is a fact, nevertheless, in strict accordance with the general laws of the distribution of species; since, in other parts of the globe, we find peculiarities of form, structure, and habit, in birds, reptiles, insects, or plants, confined entirely to one hemisphere, or one continent, and sometimes to much narrower limits.

In the south of Africa.—The southern region of Africa, where that continent extends into the temperate zone, constitutes another separate zoological province, surrounded as it is on three sides by the ocean, and cut off from the countries of milder climate, in the northern hemisphere, by the intervening torrid zone. In many instances, this region contains the same genera which are found in temperate climates to the northward

* Description of the Equatorial Regions.

† Temminck, Mammologie.

of the line; but then the southern are different from the northern species. Thus in the south we find the quagga and the zebra: in the north, the horse, the ass, and the jiggetai of Asia.

The south of Africa is spread out into fine level plains from the tropic to the Cape; in this region, says Pennant, besides the horse genus, of which five species have been found, there are also peculiar species of rhinoceros, the hog, and the hyrax, among pachydermatous races; and amongst the ruminating, the giraffe, the Cape buffalo, and a variety of remarkable antelopes, as the springbok, the oryx, the gnou, the leucophoë, the pygarga, and several others *.

In the Indian archipelago.—The Indian archipelago presents peculiar phenomena in regard to its indigenous mammalia, which, in their generic character, recede in some respects from that of the animals of the Indian continent, and approximate to the African. The Sunda isles contain a hippopotamus, which is wanting in the rivers of Asia; Sumatra, a peculiar species of tapir, and a rhinoceros resembling the African more than the Indian species, but specifically distinguishable from both †.

Beyond the Indian archipelago is an extensive region, including New Guinea, New Britain, and New Ireland, together with the archipelago of Solomon's Islands, the New Hebrides, and Louisiade, and the more remote groups of isles in the great southern ocean, which may be considered as forming one zoological province. Although these remarkable countries are extremely fertile in their vegetable productions, they are almost wholly destitute of native warm-blooded quadrupeds, except a few species of bats, and some domesticated animals in the possession of the natives ‡.

Quadrupeds in Islands.—Quadrupeds found on islands

* Pennant's Hist. of Quadrupeds, cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 66.

† Prichard, Phys. Hist. of Mankind, p. 66; Cuvier, Ann. du Museum, tom. vii.

‡ Prichard, ibid., p. 56.

situated near the continents, generally form a part of the stock of animals belonging to the adjacent main land; 'but small islands remote from continents are in general altogether destitute of land quadrupeds, except such as appear to have been conveyed to them by men. Kerguelen's Land, Juan Fernandez, the Gallapagos, and the Isles de Lobos, are examples of this fact. Among all the groups of fertile islands in the Pacific Ocean, no quadrupeds have been found, except dogs, hogs, rats, and a few bats. The bats have been found in New Zealand and the more westerly groups; they may probably have made their way along the chain of islands which extend from the shores of New Guinea far into the Southern Pacific. The hogs and the dogs appear to have been conveyed by the natives from New Guinea. The Indian isles, near New Guinea, abound in oxen, buffaloes, goats, deer, hogs, dogs, cats, and rats; but none of them are said to have reached New Guinea, except the hog and the dog. The New Guinea hog is of the Chinese variety, and was probably brought from some of the neighbouring isles, being the animal most in request among savages. It has run wild in New Guinea. Thence it has been conveyed to the New Hebrides, the Tonga and Society Isles, and to the Marquesas; but it is still wanting in the more easterly islands, and, to the southward, in New Caledonia.

'Dogs may be traced from New Guinea to the New Hebrides and Fiji isles; but they are wanting in the Tonga isles, though found among the Society and Sandwich islanders, by some of whom they are used for food: to the southward they have been conveyed to New Caledonia and New Zealand. In Easter Island, the most remotely situated in this ocean, there are no domestic animals except fowls and rats, which are eaten by the natives: these animals are found in most of the islands; the fowls are probably from New Guinea. Rats are to be found even on some desert islands, whither they may have been conveyed by canoes which have occasionally approached

the shores. It is known, also, that rats occasionally swim in large numbers to considerable distances *.'

Geographical range of the Cetacea.—It is natural to suppose that the geographical range of the different species of cetacea, should be less correctly ascertained than that of the terrestrial mammifers. It is, however, well known that the whales which are obtained by our fishers in the South Seas, are distinct from those of the North; and the same dissimilarity has been found in all the other marine animals of the same class, so far as they have yet been studied by naturalists.

Dispersion of Quadrupeds.—Let us now inquire what facilities the various land quadrupeds enjoy of spreading themselves over the surface of the earth. In the first place, as their numbers multiply, all of them, whether they feed on plants, or prey on other animals, are disposed to scatter themselves gradually over as wide an area as is accessible to them. But before they have extended their migrations over a large space, they are usually arrested either by the sea, or a zone of uncongenial climate, or some lofty and unbroken chain of mountains, or a tract already occupied by a hostile and more powerful species.

Their powers of swimming.—Rivers and narrow friths can seldom interfere with their progress, for the greater part of them swim well, and few are without this power when urged by danger and pressing want. Thus, amongst beasts of prey, the tiger is seen swimming about among the islands and creeks in the delta of the Ganges, and the jaguar traverses with ease the largest streams in South America †. The bear, also, and the bison, stem the current of the Mississippi. The popular error, that the common swine cannot escape by swimming when thrown into the water, has been contradicted by several curious and well-authenticated instances during the recent floods in Scotland. One pig, only six months old, after having been carried down from Garmouth to the bar at the

* Prichard, Phys. Hist. of Mankind, vol. i. p. 75.

† Buffon, vol. v. p. 204.

mouth of the Spey, a distance of a quarter of a mile, swam four miles eastward to Port Gordon and landed safe. Three others, of the same age and litter, swam at the same time five miles to the west, and landed at Blackhill *.

In an adult and wild state, these animals would doubtless have been more strong and active, and might, when hard pressed, have performed a much longer voyage. Hence islands remote from the continent may obtain inhabitants by casualties which, like the late storms in Morayshire, may only occur once in many centuries, or thousands of years, under all the same circumstances. It is obvious that powerful tides, winds, and currents, may sometimes carry along quadrupeds capable, in like manner, of preserving themselves for hours in the sea to very considerable distances, and in this way, perhaps, the tapir (*Tapir Indicus*) may have become common to Sumatra and the Malayan peninsula.

To the elephant, in particular, the power of crossing rivers is essential in a wild state, for the quantity of food which a herd of these animals consumes renders it necessary that they should be constantly moving from place to place. The elephant crosses the stream in two ways. If the bed of the river be hard, and the water not of too great a depth, he fords it. But when he crosses great rivers, such as the Ganges and the Niger, the elephant swims deep, so deep that the end of his trunk only is out of the water; for it is a matter of indifference to him whether his body be completely immersed, provided he can bring the tip of his trunk to the surface, so as to breathe the external air.

Animals of the deer kind frequently take to the water, especially in the rutting season, when the stags are seen swimming for several leagues at a time, from island to island, in search of the does, especially in the Canadian lakes; and in some countries where there are islands near the sea-shore, they fearlessly enter the sea and swim to them. In hunting excur-

* Sir T. D. Lauder, Bart., on the Floods in Morayshire, August 1829, p. 302, second edition.

sions, in North America, the elk of that country is frequently pursued for great distances through the water.

The large herbivorous animals, which are gregarious, can never remain long in a confined region, as they consume so much vegetable food. The immense herds of bisons which often, in the great valley of the Mississippi, blacken the surface near the banks of that river and its tributaries, are continually shifting their quarters, followed by wolves which prowl about in their rear. 'It is no exaggeration,' says Mr. James, 'to assert, that in one place, on the banks of the Platte, at least ten thousand bisons burst on our sight in an instant. In the morning we again sought the living picture, but upon all the plain, which last evening was so teeming with noble animals, not one remained *.'

Migratory instincts.—Besides the disposition common to the individuals of every species slowly to extend their range in search of food, in proportion as their numbers augment, a migratory instinct often develops itself in an extraordinary manner, when, after an unusually prolific season, or upon a sudden scarcity of provisions, great multitudes are threatened by famine. We shall enumerate several illustrations of these migrations, because they may put us upon our guard against attributing a high antiquity to a particular species merely because it is diffused over a great space; they show clearly how soon, in a state of nature, a newly-created species might spread itself, in every direction, from a single point.

In very severe winters, great numbers of the black bears of America migrate from Canada into the United States; but in milder seasons, when they have been well fed, they remain and hybernate in the north †. The rein-deer, which in Scandinavia can scarcely exist to the south of the sixty-fifth parallel, descends, in consequence of the greater coldness of the climate, to the fiftieth degree, in Chinese Tartary, and often roves

* Expedition from Pittsburg to the Rocky Mountains, vol. ii. p. 153.

† Richardson's Fauna Boreali-Americana, p. 16.

into a country of more southern latitude than any part of England.

In Lapland, and other high latitudes, the common squirrels, whenever they are compelled, by want of provisions, to quit their usual abodes, migrate in amazing numbers, and travel directly forwards, allowing neither rocks, forests, nor the broadest waters, to turn them from their course. Great numbers are often drowned in attempting to pass friths and rivers. In like manner the small Norway rat sometimes pursues its migrations in a straight line across rivers and lakes; and Pennant informs us that when, in Kamtschatka, the rats become too numerous, they gather together in the spring, and proceed in great bodies westward, swimming over rivers, lakes, and arms of the sea. Many are drowned or destroyed by water-fowl or fish. As soon as they have crossed the river Penchim, at the head of the gulf of the same name, they turn southward, and reach the rivers Judoma and Ochot by the middle of July, a district surprisingly distant from their point of departure.

The lemings, also, of Scandinavia, often pour down in myriads from the northern mountains and devastate the country. They generally move in lines which are about three feet from each other, and exactly parallel, and they direct their march from the north-west to the south-east, going directly forward through rivers and lakes, and when they meet with stacks of hay or corn, gnawing their way through them instead of passing round *.

Vast troops of the wild ass, or *onager* of the ancients, which inhabit the mountainous deserts of Great Tartary, feed, during the summer, in the tracts east and north of Lake Aral. In the autumn they collect in herds of hundreds, and even thousands, and direct their course towards the north of India, and often to Persia, to enjoy a warm retreat during winter †. Bands of two or three hundred quaggas, a species of wild ass, are sometimes seen to migrate from the tropical plains of southern

* Phil. Trans., vol. ii. p. 872. † Wood's Zoography, vol. i. p. 11.

Africa to the vicinity of the Malaleveen river. During their migrations they are followed by lions, who slaughter them night by night *.

The migratory swarms of the springbok, or Cape antelope, afford another illustration of the rapidity with which a species, under certain circumstances, may be diffused over a continent. When the stagnant pools of the immense deserts south of the Orange river dry up, which often happens after intervals of three or four years, myriads of these animals desert the parched soil, and pour down like a deluge on the cultivated regions nearer the Cape. The havoc committed by them resembles that of the African locusts; and so crowded are the herds, that 'the lion has been seen to walk in the midst of the compressed phalanx with only as much room between him and his victims as the fears of those immediately around could procure by pressing outwards †.'

Dr. Horsfield mentions a singular fact in regard to the geographical distribution of the Mydaus meliceps, a kind of polecat inhabiting Java. This animal is 'confined exclusively to those mountains which have an elevation of more than seven thousand feet above the level of the ocean: on these it occurs with the same regularity as many plants. The long-extended surface of Java, abounding with conical points which exceed this elevation, affords many places favourable for its resort. On ascending these mountains, the traveller scarcely fails to meet with this animal, which, from its peculiarities, is universally known to the inhabitants of these elevated tracts, while to those of the plains it is as strange as an animal from a foreign country. In my visits to the mountainous districts, I uniformly met with it, and, as far as the information of the natives can be relied on, it is found on all the mountains ‡.'

* On the authority of Mr. Campbell. Library of Entert. Know., Menageries, vol. i. p. 152.

† Cuvier's Animal Kingdom, by Griffiths, vol. ii. p. 109. Library of Entert. Know., Menageries, vol. i. p. 366.

‡ Zoological Researches in Java, No. 2.

Now, if we were asked to conjecture how the Mydaus arrived at the elevated regions of each of these isolated mountains, we should say that before the isle was peopled by man, by whom their numbers are now thinned, they may occasionally have multiplied so as to be forced to collect together and migrate; in which case, notwithstanding the slowness of their motions, some few would succeed in reaching another mountain, some twenty, or even, perhaps, fifty miles distant: for although the climate of the hot intervening plains would be unfavourable to them, they might support it for a time, and would find there abundance of insects on which they feed. Volcanic eruptions, which at different times have covered the summits of some of these lofty cones with steril sand and ashes, may have occasionally contributed to force on these migrations.

Drifting of animals on ice-floes.—The power of the terrestrial mammalia to cross the sea is very limited, and we have already stated that the same species is scarcely ever common to districts widely separated by the ocean. If there be some exceptions to this rule they generally admit of explanation, for there are natural means whereby some animals may be floated across the water, and the sea sometimes wears a passage through a neck of land, leaving individuals of a species on each side of the new channel. Polar bears are known to have been frequently drifted on the ice from Greenland to Iceland; they can also swim to considerable distances, for Captain Parry, on the return of his ships through Barrow's Strait, met with a bear swimming in the water about midway between the shores, which were about forty miles apart, and where no ice was in sight *. 'Near the east coast of Greenland,' observes Scoresby, 'they have been seen on the ice in such quantities, that they were compared to flocks of sheep on a common—and they are often found on field-ice, above two hundred miles from the shore †.' Wolves, in the arctic regions, often venture upon the ice near the shore, for the purpose of preying upon young

* Append. to Parry's Second Voyage, years 1819-20.

† Account of the Arctic Regions, vol. i. p. 518.

seals which they surprise when asleep. When these ice-floes get detached, the wolves are often carried out to sea, and though some may be drifted to islands or continents, the greater part of them perish, and have been often heard in this situation howling dreadfully, as they die by famine *.

During the short summer which visits Melville Island, various plants push forth their leaves and flowers the moment the snow is off the ground, and form a carpet spangled with the most lively colours. These secluded spots are reached annually by herds of musk-oxen and rein-deer, which travel immense distances over dreary and desolate regions, to graze undisturbed on these luxuriant pastures †. The rein-deer often pass along in the same manner, by the chain of the Aleutian Islands, from Behring's Straits to Kamtschatka, subsisting on the moss found in these islands during their passage ‡.

On floating islands of drift-wood.—Within the tropics there are no ice-floes; but, as if to compensate for that mode of transportation, there are floating isles of matted trees, which are often borne along through considerable spaces. These are sometimes seen sailing at the distance of fifty or one hundred miles from the mouth of the Ganges, with living trees standing erect upon them. The Amazon, the Congo, and the Orinoco, also produce these verdant rafts, which are formed in the manner already described when speaking of the great raft of the Atchafalaya, an arm of the Mississippi, where a natural bridge of timber, ten miles long, and more than two hundred yards wide, has existed for more than forty years, supporting a luxurious vegetation, and rising and sinking with the water which flows beneath it §. That this enormous mass will one day break up and send down a multitude of floating islands to the gulf of Mexico, is the hope and well-founded expectation of the inhabitants of Louisiana.

On these green isles of the Mississippi, observes Malte-

* Turton, in a note to Goldsmith's Nat. Hist., vol. iii. p. 43.

† Supplement to Parry's First Voyage of Disc., p. 189.

‡ Godman's American Nat. Hist., vol. i. p. 22.

§ See ante, vol. i. chap. xi.

Brun *, young trees take root, and the pisliar and nenuphar display their yellow flowers: there serpents, birds, and the cayman alligator, come to repose, and all are sometimes carried to the sea, and engulphed in its waters.

In a memoir lately published, a naval officer informs us, that as he returned from China by the eastern passage, he fell in, among the Moluccas, with several small floating islands of this kind, covered with mangrove-trees interwoven with underwood. The trees and shrubs retained their verdure, receiving nourishment from a stratum of soil which formed a white beach round the margin of each raft, where it was exposed to the washing of the waves and the rays of the sun †. The occurrence of soil in such situations may easily be explained, for all the natural bridges of timber which occasionally connect the islands of the Ganges, Mississippi, and other rivers, with their banks, are exposed to floods of water, densely charged with sediment.

Captain W. H. Smyth informs me, that when cruizing in the Cornwallis amidst the Philippine Islands, he has more than once seen, after those dreadful hurricanes called typhoons, floating islands of wood, with trees growing upon them, and that ships have sometimes been in imminent peril, in consequence of mistaking them for terra-firma.

It is highly interesting to trace, in imagination, the effects of the passage of these rafts from the mouth of a large river to some archipelago, such as those in the South Pacific, raised from the deep, in comparatively modern times, by the operations of the volcano and the earthquake, and the joint labours of coral animals and testacea. If a storm arise, and the frail vessel be wrecked, still many a bird and insect may succeed in gaining, by flight, some island of the newly-formed group, while the seeds and berries of herbs and shrubs, which fall into the waves, may be thrown upon the strand. But if the surface of the deep be calm, and the rafts are carried along by a cur-

* System of Geography, vol. v. p. 157.

† United Service Journal, No. 24, p. 697.

rent, or wafted by some slight breath of air fanning the foliage of the green trees, it may arrive, after a passage of several weeks, at the bay of an island, into which its plants and animals may be poured out as from an ark, and thus a colony of several hundred new species may at once be naturalized.

We may remind the reader, that we merely advert to the transportation of these rafts as of extremely rare and accidental occurrence; but it may account, in tropical countries, for some of the rare exceptions to the general law, of the confined range of species.

Migrations of the Cetacea.—Many of the cetacea, the whales of the northern seas for example, are found to desert one tract of the sea, and to visit another very distant, when they are urged by want of food or danger. The seals also retire from the coasts of Greenland in July, return again in September, and depart again in March, to return in June. They proceed in great droves northwards, directing their course where the sea is most free from ice, and are observed to be extremely fat when they set out on this expedition, and very lean when they come home again *.

Species of the Mediterranean, Euxine, and Caspian, identical.—Some naturalists have wondered that the sea calves, dolphins, and other marine mammalia of the Mediterranean and Euxine should be identical with those found in the Caspian; and among other fanciful theories, they have suggested that they may dive through subterranean conduits, and thus pass from one sea into the other. But as the occurrence of wolves and other noxious animals, on both sides of the British channel, was adduced by Desmarest, as one of many arguments to prove that England and France were once united, so the correspondence of the aquatic species of the inland seas of Asia with those of the Black Sea, tends to confirm the hypothesis for which there are abundance of independent geological data, that those seas were connected together by straits at no remote period of the earth's history.

* Krautz, vol. i. p. 129, cited by Goldsmith, Nat. Hist., vol. iii. p. 260.

Geographical Distribution and Migrations of Birds.

We shall now offer a few observations on some of the other divisions of the animal kingdom. Birds, notwithstanding their great locomotive powers, form no exception to the general rules already laid down, but, in this class as in plants and terrestrial quadrupeds, different groups of species are circumscribed within definite limits. We find, for example, one assemblage in the Brazils, another in the same latitudes in central Africa, another in India, and a fourth in New Holland. But some species again are so local, that in the same archipelago, a single island frequently contains a species found in no other spot on the whole earth; as is exemplified in some of the parrot tribes. In this extensive family, which are, with few exceptions, inhabitants of tropical regions, the American group has not one in common with the African, nor either of these with the parrots of India *.

Another illustration is afforded by that minute and beautiful tribe, the humming birds. The whole of them are, in the first place, peculiar to the new world; but there, although some have a considerable range, as the *Trochilus flammifrons* which is common to Lima, the island of Juan Fernandez and the Straits of Magellan †, other species are peculiar to some of the West India islands, and have not been found elsewhere in the western hemisphere. The ornithology of our own country affords a no less striking exemplification of the same law, for the common grouse (*Tetrao scoticus*) occurs nowhere in the known world except in the British isles.

Some species of the vulture tribe are said to be true cosmopolites, and the common wild goose, *Anas anser,* Linn., if we may believe some ornithologists, is a general inhabitant of the globe, being met with from Lapland to the Cape of

* Prichard, vol. i. p. 47.

† Captain King, during his late survey, found this bird at the Straits of Magellan, in the month of May, the depth of winter, sucking the flowers of the large species of fuchsia, then in bloom in the midst of a shower of snow.

Good Hope, frequent in Arabia, Persia, China, and Japan, and in the American continent, from Hudson's Bay to South Carolina *. An extraordinary range has also been attributed to the nightingale, which extends from western Europe to Persia, and still farther. In a work entitled Specchio Comparativo †, by Charles Bonaparte, many species of birds are enumerated as common to Rome and Philadelphia; the greater part of these are migratory, but some of them, such as the long-eared owl, *Strix otus*, are permanent in both countries.

Their facilities of diffusion.—In parallel zones of the northern and southern hemispheres, a great general correspondence of form is observable, both in the aquatic and terrestrial birds, but there is rarely any specific identity; and this phenomenon is truly remarkable, when we recollect the readiness with which some birds, not gifted with great powers of flight, shift their quarters to different regions, and the facility with which others, possessing great strength of wing, perform their aërial voyages. Some migrate periodically from high latitudes, to avoid the cold of winter, and the accompaniments of cold,—scarcity of insects and vegetable food; others, it is said, for some particular kinds of nutriment required for rearing their young: for this purpose, they often traverse the ocean for thousands of miles, and recross it at other periods, with equal security.

Periodical migrations, no less regular, are mentioned by Humboldt, of many American water-fowl, from one part of the tropics to another in a zone where there is the same temperature throughout the year. Immense flights of ducks leave the valley of the Orinoco, when the increasing depth of its waters and the flooding of its shores prevent them from catching fish, insects, and aquatic worms. They then betake themselves to the Rio Negro and Amazon, having passed from the eighth and third degrees of north latitude, to the first and

* Bewick's Birds, vol. ii. p. 294, who cites Latham.

† Pisa, 1827 (not sold).

fourth of south latitude, directing their course south-south-east. In September, when the Orinoco decreases and re-enters into its channel, these birds return northwards *.

The insectivorous swallows which visit our island would perish during winter, if they did not annually repair to warmer climes. It is supposed, that in these aërial excursions the average rapidity of their flight is not less than fifty miles an hour, so that, when aided by the wind, they soon reach warmer latitudes. Spallanzani calculated that the swallow can fly at the rate of ninety-two miles an hour, and conceived that the rapidity of the swift might be three times greater †. The rate of flight of the eider duck (*Anas mollissima*) has been ascertained to be ninety miles an hour; and that of hawks and several other tribes to be one hundred and fifty miles.

When we reflect how easily different species, in a great lapse of ages, may be each overtaken by gales and hurricanes, and, abandoning themselves to the tempest, be scattered at random through various regions of the earth's surface, where the temperature of the atmosphere, the vegetation, and the animal productions, might be suited to their wants, we shall be prepared to find some species capriciously distributed, and to be sometimes unable to determine the native countries of each. Captain Smyth informs me, that when engaged in his survey of the Mediterranean, he encountered a gale in the gulf of Lyons, at the distance of between twenty and thirty leagues from the coast of France, which bore along many land birds of various species, some of which alighted on the ship, while others were thrown with violence against the sails. In this manner islands become tenanted by species of birds inhabiting the nearest main land.

Geographical Distribution and Dissemination of Reptiles.

A few facts respecting the third great class of vertebrated animals will suffice to show that the plan of nature in regard

* Voyage aux Régions Equinoxiales, tome vii. p. 429.

† Fleming, Phil. Zool., vol. ii. p. 43.

to their location on the globe is perfectly analogous to that already exemplified in other parts of the organic creation, and has probably been determined by similar causes.

Habitations of Reptiles.—Of the great saurians, the gavials which inhabit the Ganges, differ from the cayman of America, or the crocodile of the Nile. The monitor of New Holland is specifically distinct from the Indian species; these latter again from the African, and all from their congeners in the new world. So in regard to snakes; we find the boa of America, represented by the python, a different though nearly allied genus, in India. America is the country of the rattle-snake, Africa of the cerastes, and Asia of the hooded snake or cobra di capello.

Reptiles in Ireland.—There is a legend that St. Patrick expelled all reptiles from Ireland, and certain it is that none of the three species of snakes common in England, nor the toad, have been observed there by naturalists. They have our common frog, and our water-newt, and according to Ray (Quad. 264.) the green lizard (*Lacerta viridis*). Schultes the botanist observed, a few years since, in his tour in England, that there were two great islands in Europe of which the floras were unknown, Sardinia and Ireland; we believe he might also have added the fauna of the latter country.

Migrations of the larger Reptiles.—The range of the large reptiles is, in general, quite as limited as that of some orders of the terrestrial mammalia. The great saurians sometimes cross a considerable tract, in order to pass from one river to another; but their motions by land are generally slower than those of quadrupeds. By water, however, they may transport themselves to distant situations more easily. The larger alligator of the Ganges sometimes descends beyond the brackish water of the Delta into the sea, and in such cases it might chance to be drifted away by a current, and survive till it reached a shore at some distance; but such casualties are probably very rare *.

* Malte-Brun says (Syst. of Geog., vol. viii. p. 193), that a crocodile is still pre-

Migrations of Turtles.—Turtles migrate in large droves from one part of the ocean to another during the ovipositing season. Dr. Fleming * mentions that an individual of the hawk's bill turtle (*Chelonia imbricata*) so common in the American seas, has been taken at Papa Stour, one of the West Zetland islands; and according to Sibbald, 'the same animal came into Orkney.' Another was taken in 1774, in the Severn according to Turton. Two instances also of the occurrence of the leathern tortoise (*C. coriacea*), on the coast of Cornwall, in 1756, are mentioned by Borlase. These animals of more southern seas can only be considered as stragglers attracted to our shores during uncommonly warm seasons by an abundant supply of food, or driven by storms to high latitudes.

Boa Constrictor drifted by currents to St. Vincent's.—Some of the smaller reptiles lay their eggs on aquatic plants; and these must often be borne rapidly by rivers, and conveyed to distant regions in a manner similar to the dispersion of seeds before adverted to. But that the larger ophidians may be themselves transported across the seas is evident from the following most interesting account of the arrival of one at the island of St. Vincent. It is worthy of being recorded, says the Rev. L. Guilding †, 'that a noble specimen of the *Boa constrictor* was lately conveyed to us by the currents, twisted round the trunk of a large sound cedar tree, which had probably been washed out of the bank by the floods of some great South American river, while its huge folds hung on the branches, as it waited for its prey. The monster was fortunately destroyed after killing a few sheep, and his skeleton now hangs before me in my study, putting me in mind how much reason I might have had to fear in my future rambles through the forests of St. Vincent, had this formidable reptile been a pregnant female, and escaped to a safe retreat.'

served at Lyons that was taken from the *Rhone*, about two centuries ago; but no particulars are given.

* Brit. Animals, p. 149; who cites Sibbald.

† Zool. Journ., vol. iii. p. 406. Dec. 1827.

CHAPTER VII.

Laws which regulate the geographical distribution of species, *continued*—Geographical distribution and migrations of fish—of testacea—Causes which limit the extension of many species—Their mode of diffusion—Geographical range of zoophytes—Their powers of dissemination—Distribution of insects—Migratory instincts of some species—Certain types characterize particular countries—Their means of dissemination—Geographical distribution and diffusion of man—Speculations as to the birth-place of the human species—Progress of human population—Drifting of canoes to vast distances—On the involuntary influence of man in extending the range of many other species.

LAWS WHICH REGULATE THE GEOGRAPHICAL DISTRIBUTION OF SPECIES, *continued.*

Geographical Distribution and Migrations of Fish.—Although we are less acquainted with the habitations of marine animals than with the grouping of the terrestrial species before described, yet it is well ascertained that their distribution is governed by the same general laws. The testimony borne by MM. Péron and Lesueur to this important fact is remarkably strong. These eminent naturalists, after collecting and describing many thousand species of marine animals which they brought to Europe from the southern hemisphere, insist most emphatically on their distinctness from those north of the equator; and this remark they extend to animals of all classes, from those of a more simple to those of a more complex organization, from the sponges and medusæ to the cetacea. 'Among all those which we have been able to examine,' say they, 'with our own eyes, or with regard to which it has appeared to us possible to pronounce with certainty, there is not a single animal of the southern regions which is not distinguished by essential characters from the analogous species in the northern seas *.'

The fish of the Arabian gulf are said to differ entirely from

* Sur les Habitations des Animaux Marins.—Ann. du Mus., tom. xv., cited by Prichard, Phys. Hist. of Mankind, vol. i. p. 51.

those of the Mediterranean, notwithstanding the proximity of these seas. The flying-fish are found (some stragglers excepted) only between the tropics,--in receding from the line they never approach a higher latitude than the fortieth parallel. Those inhabiting the Atlantic are said to be different species from those of the eastern ocean *. The electric gymnotus belongs exclusively to America, the trembler, or *Silurus electricus*, to the rivers of Africa; but the torpedo, or crampfish, is said to be dispersed over all tropical and many temperate seas †.

All are aware that there are certain fish of passage which have their periodical migrations like some tribes of birds. The salmon, towards the season of spawning, ascends the rivers for hundreds of miles, leaping up the cataracts which it meets in its course, and then retreats again into the depths of the ocean. The herring and the haddock, after frequenting certain shores in vast shoals for a series of years, desert them again and resort to other stations, followed by the species which prey on them. Eels are said to descend into the sea for the purpose of producing their young, which are seen returning into the fresh water by myriads, extremely small in size, but possessing the power of surmounting every obstacle which occurs in the course of a river, by applying their slimy and glutinous bodies to the surface of rocks, or the gates of a lock, even when dry, and so climbing over it ‡.

Gmelin says, that the anseres subsist in their migrations on the spawn of fish, and that oftentimes when they void the spawn, two or three days afterwards, the eggs retain their vitality unimpaired §. When there are many disconnected freshwater lakes in a mountainous region, at various elevations, each remote from the other, it has often been deemed inconceivable how they could all become stocked with fish from one common source; but it has been suggested, that the minute eggs of these animals may sometimes be entangled in the fea-

* Malte-Brun, vol. i. p. 507.

† Ibid.

‡ Phil. Trans., 1747, p. 395.

§ Amœn. Acad., Essay 75.

thers of water-fowl. These, when they alight to wash and plume themselves in the water, may often unconsciously contribute to propagate swarms of fish, which, in due season, will supply them with food. Some of the water-beetles, also, as the dyticidæ, are amphibious, and in the evening quit their lakes and pools, and flying in the air transport the minute ova of fishes to distant waters. In this manner some naturalists account for the fry of fish appearing occasionally in small pools caused by heavy rains.

Geographical Distribution and Migrations of Testacea.

The testacea, of which so great a variety of species occurs in the sea, are a class of animals of peculiar importance to the geologist, because their remains are found in strata of all ages, and generally in a higher state of preservation than those of other organic beings. Climate has a decided influence on the geographical distribution of species in this class; but as there is much greater uniformity of temperature in the waters of the ocean, than in the atmosphere which invests the land, the diffusion of many marine molluscs is extensive.

Causes which limit the extension of many species.—Some forms, as those of the nautili, volutæ, and cyprææ, attain their fullest development in warm latitudes; and most of their species are exclusively confined to them. Péron and Lesueur remark, that the Haliotis gigantea, of Van Diemen's land, and the Phasianella, diminish in size as they follow the coasts of New Holland to King George's Sound, and entirely disappear beyond them *. Almost all the species of South American shells differ from those of the Indian archipelago in the same latitudes; and on the shores of many of the isles of the South Pacific, peculiar species have been obtained. But we are as yet by no means able to sketch out the submarine provinces of shells, as the botanist has done those of the terrestrial, and even of the subaqueous plants. There can be little doubt, however, that the boundaries in this case, both of latitude and longitude,

* Ann. du Mus. d'Hist. Nat., tom. xv.

will be found in general well defined. The continuous lines of continents, stretching from north to south, prevent a particular species from belting the globe, and following the direction of the isothermal lines. The inhabitants of the West Indian seas, for example, cannot enter the Pacific without passing round through the inclement climate of Cape Horn. Currents also flowing permanently in certain directions, and the influx at certain points of great bodies of fresh water, limit the extension of many species. Those which love deep water are arrested by shoals; others, fitted for shallow seas, cannot migrate across unfathomable abysses.

Great range of some species.—Some few species, however, have an immense range, as the *Bulla aperta* for example, which is found in almost all zones. The habitation of the *Bulla striata* extends from the shores of Egypt to the coasts of England and France, and it recurs again in the seas of Senegal, Brazil, and the West Indies. The *Turbo petræus* inhabits the seas of England, Guadaloupe, and the Cape of Good Hope *, and many instances of a similar kind might be enumerated.

The *Ianthina fragilis* has wandered into almost every sea, both tropical and temperate. This 'common oceanic snail' derives its buoyancy from an admirably-contrived float, which has enabled it not only to disperse itself so universally, but to become an active agent in disseminating other species which attach themselves, or their ova, to its shell †.

It is evident that among the testacea, as in plants and the higher order of animals, there are species which have a power of enduring a wide range of temperature, whereas others cannot resist a considerable change of climate. Among the freshwater molluscs, and those which breathe air, Férrussac

* Fér. Art. Geogr. Phys. Dict. Class. d'Hist. Nat.

† Mr. Broderip possesses specimens of *Ianthina fragilis*, bearing more than one species of barnacle (*Pentelasmis*), presented to him by Captain King and Lieutenant Graves. One of these specimens, taken alive by Captain King far at sea, and a little north of the equator, is so loaded with those cirrhipeds, and with numerous ova, that all the upper part of its shell is invisible.

mentions a few instances of species of almost universal diffusion.

The Helix putris (*Succinea putris*, Lam.), so common in Europe, where it reaches from Norway to Italy, is also found in Egypt, in the United States, in Newfoundland, Jamaica, Tranquebar, and, it is even said, in the Marianne Isles. As this animal inhabits constantly the borders of pools and streams where there is much moisture, it is not impossible that different water-fowl have been the agents of spreading some of its minute eggs, which may have been entangled in their feathers. *Helix aspersa,* one of the commonest of our larger land-shells, is found in South America, at the foot of Chimborazo, as also in Cayenne. Some conchologists have conjectured that it was accidentally imported in some ship; for it is an eatable species, and these animals are capable of retaining life, during long voyages, without air or nourishment*.

Confined range of others.—Mr. Lowe, in a memoir just published in the Cambridge Transactions, enumerates seventy-one species of land mollusca, collected by him in the islands of Madeira and Porto Santo, sixty of which belonged to the genus Helix alone, including as subgenera Bulimus and Achatina, and excluding Vitrina and Clausilia;—forty-four of these are new. It is remarkable that very few of the above-mentioned species are common to the neighbouring archipelago of the Canaries; but it is a still more striking fact that, of the sixty species of the three genera above mentioned, thirty-one are natives of Porto Santo; whereas, in Madeira, which contains ten times the superficies, were found but twenty-nine. Of these only four were common to the two islands, which are only

* Four individuals of a large species of Bulimus, from Valparaiso, were brought to England by Lieutenant Graves, who accompanied Captain King in his late expedition to the Straits of Magellan. They had been packed up in a box and enveloped in cotton, two for a space of thirteen, one for seventeen, and a fourth for upwards of twenty months; but, on being exposed by Mr. Broderip to the warmth of a fire in London, and provided with tepid water and leaves, they revived, and lived for several months in Mr. Loddiges' palm-house.

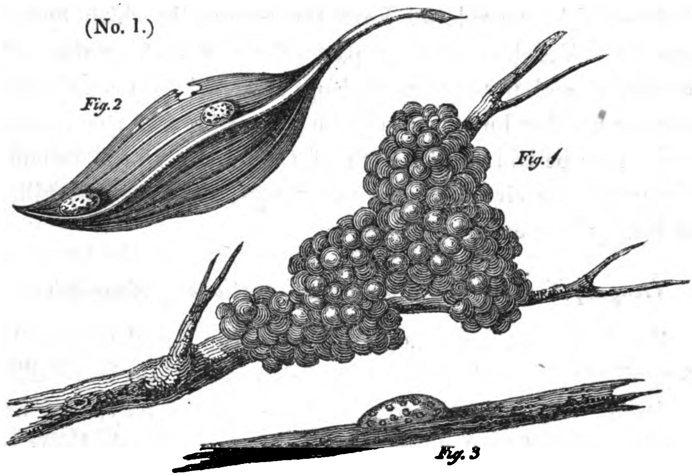
separated by a distance of twelve leagues; and two even of these four (namely, *Helix rhodostoma* and *H. ventrosa*) are species of general diffusion, common to Madeira, the Canaries, and the South of Europe *.

The confined range of these molluscs may easily be explained, if we admit that species have only one birth-place; and the only problem to be solved would relate to the exceptions—to account for the dissemination of some species throughout several isles and the European continent. May not the eggs, when washed into the sea by the undermining of cliffs, or blown by a storm from the land, float uninjured to a distant shore?

Their mode of diffusion.—Notwithstanding the proverbially slow motion of snails and molluscs in general, and although many aquatic species adhere constantly to the same rock for their whole lives, they are by no means destitute of provision for disseminating themselves rapidly over a wide area. Some lay their eggs in a sponge-like nidus, wherein the young remain enveloped for a time after their birth, and this buoyant substance floats far and wide as readily as sea-weed. The young of other viviparous tribes are often borne along, entangled in sea-weed. Sometimes they are so light that, like grains of sand, they can be easily moved by currents. Balani and serpulæ are sometimes found adhering to floating cocoa-nuts, and even to fragments of pumice. In rivers and lakes, on the other hand, aquatic univalves usually attach their eggs to leaves and sticks which have fallen into the water, and which are liable to be swept away during floods, from tributaries to the main streams, and from thence to all parts of the same basins. Particular species may thus migrate during one season from the head waters of the Mississippi, or any other great river, to countries bordering the sea, at the distance of many thousand miles.

An illustration of the mode of attachment of these eggs will be seen in the annexed cut. (No. 1.)

* Camb. Phil. Trans., vol. iv., 1831.



Eggs of fresh-water Molluscs.

Fig. 1. Eggs of Ampullaria ovata (a fluviatile species), fixed to a small sprig which had fallen into the water.

Fig. 2. Eggs of Planorbis albus, attached to a dead leaf lying under water.

Fig. 3. Eggs of the common Limneus (L. vulgaris), adhering to a dead stick under water.

The habit of some testacea to adhere to floating wood is proved by their fixing themselves to the bottoms of ships. By this mode of conveyance *Mytilus polymorphus* has been brought from northern Europe to the Commercial Docks in the Thames, where the species is now domiciled.

A lobster (*Astacus marinus*) was lately taken alive covered with living mussels (*Mytilus edulis*)*, and a large female crab (*Cancer pagurus*), covered with oysters, and bearing also anomia, ephippium, and actiniæ, was taken in April, 1832, off the English coast. The oysters, seven in number, include individuals of six years' growth, and the two largest are four inches long and three inches and a half broad. Both the crab and the oysters were seen alive by Mr. Robert Brown †.

* The specimen is preserved in the Museum of the Zool. Soc. of London.

† This specimen is in the collection of my friend Mr. Broderip, who observes that this crab, which was apparently in perfect health, could not have cast her shell for six years, whereas some naturalists have stated that the species moults

From this example we learn the manner in which oysters may be diffused over every part of the sea where the crab wanders; and if they are at length carried to a spot where there is nothing but fine mud, the foundation of a new oyster-bank may be laid on the death of the crab. In this instance the oysters survived the crab many days, and were only killed at last by long exposure to the air.

Geographical Distribution and Migrations of Zoophytes.

Zoophytes are very imperfectly known, but there can be little doubt that each maritime region possesses species peculiar to itself. The madrepores, or lamelliferous polyparia, are found in their fullest development only in the tropical seas of Polynesia and the East and West Indies, and this family is represented only by a few species in our seas. Those even of the Mediterranean are inferior in size, and, for the most part, different from such as inhabit the tropics. Péron and Lesueur, after studying the Holothuriæ, Medusæ, and other congeners of delicate and changeable forms, came to the conclusion that each kind has its place of residence determined by the temperature necessary to support its existence. Thus, for example, they found the abode of Pyrosoma Atlantica to be confined to one particular region of the Atlantic ocean*.

Their powers of dissemination.—Let us now inquire how the transportation of polyps from one part of the globe to another is effected. Many of them, as in the families Flustra and Sertularia, attach themselves to sea-weed, and are occasionally drifted along with it. Many fix themselves to the shells of gasteropods, and are thus borne along by them to short distances. Some polyps, like the sea-pens, swim freely about in the sea. But the most frequent mode of transportation probably consists in the buoyancy of their eggs, or certain small vesicles which are detached and are capable of becoming

annually, without limiting the moulting period to the early stages of growth of the animal.

* Voy. aux Terres Australes, tome i. p. 492.

the foundation of a new colony. These gems, as they have been called, may be swept along by a wave that breaks upon a coral reef, and may then be borne by a current to a distance.

That some zoophytes adhere to floating bodies is proved by their being found attached to the bottoms of ships, as in the case of testacea before alluded to.

Geographical Distribution and Migrations of Insects.

Before we conclude our sketch of the manner in which the habitable parts of the earth are shared out among particular assemblages of organic beings, we must offer a few remarks on insects, which, by their numbers, and the variety of their powers and instincts, exert a prodigious influence in the economy of animate nature. As a large portion of these minute creatures are strictly dependent for their subsistence on certain species of vegetables, the entomological provinces must coincide in a considerable degree with the botanical.

Certain types characterize particular countries.—All the insects, says Latreille, brought from the eastern parts of Asia and China, whatever be their latitude and temperature, are distinct from those of Europe and of Africa. The insects of the United States, although often they approach very close to our own, are nevertheless specifically distinguishable by some characters. In South America, the equinoctial lands of New Grenada and Peru on the one side, and of Guiana on the other, contain for the most part distinct groups; the Andes forming the division, and interposing a narrow line of severe cold between climates otherwise very similar *.

Migratory instincts.—The insects of the United States, even those of the northern provinces as far as Canada, differ specifically from the European, while those of Greenland appear to be in a great measure identical with our own. Some insects are very local, while a few, on the contrary, are common to remote countries, between which the torrid zone and the ocean

* Géographie Générale des Insectes et des Arachnides. Mém. du Mus. d'Hist Nat., tome iii.

intervene. Thus our painted lady butterfly (*Vanessa cardui*) reappears in New Holland and Japan with scarcely a varying streak *. The same species is said to be one of the few insects which are universally dispersed over the earth, being found in Europe, Asia, Africa, and America; and its wide range is the more interesting because it seems explained by its migratory instinct, seconded, no doubt, by a capacity enjoyed by few species, of enduring a great diversity of temperature.

A vast swarm of this species, forming a column from ten to fifteen feet broad, was, a few years since, observed in the Canton de Vaud; they traversed the country with great rapidity from north to south, all flying onwards in regular order, close together, and not turning from their course on the approach of other objects. Professor Bonelli, of Turin, observed in March of the same year, a similar swarm of the same species, also directing their flight from north to south, in Piedmont, in such immense numbers, that at night the flowers were literally covered with them. They had been traced from Coni, Raconi, Susa, &c. A similar flight at the end of the last century is recorded by M. Louch, in the Memoirs of the Academy of Turin. The fact is the more worthy of notice, because the caterpillars of this butterfly are not gregarious, but solitary from the moment that they are hatched; and this instinct remains dormant, while generation after generation passes away, till it suddenly displays itself in full energy when their numbers happen to be in excess.

Not only peculiar species but certain types distinguish particular countries; and there are groups, observes Kirby, which represent each other in distant regions, whether in their form, their functions, or in both. Thus the honey and wax of Europe, Asia, and Africa, are in each case prepared by bees congenerous with our common hive-bee (*Apis*, Latr.); while in America, this genus is nowhere indigenous, but is replaced by Melipona and Trigona; and in New Holland by a still different, but undescribed type †.

* Kirby and Spence, vol. iv. p. 487.

† Ibid., p. 497.

Their means of dissemination.—As almost all insects are winged, they can readily spread themselves wherever their progress is not opposed by uncongenial climates, or by seas, mountains, and other physical impediments; and these barriers they can sometimes surmount by abandoning themselves to violent winds, which, as we before stated, when speaking of floating seeds, may in a few hours carry them to very considerable distances. On the Andes some sphinxes and flies have been observed by Humboldt, at the height of 19,180 feet above the sea, and which appeared to him to have been involuntarily carried into these regions by ascending currents of air *.

White mentions a remarkable shower of aphides which seem to have emigrated, with an east wind, from the great hop plantations of Kent and Sussex, and blackened the shrubs and vegetables where they alighted at Selbourne, spreading at the same time in great clouds all along the vale from Farnham to Alton. These aphides are sometimes accompanied by vast numbers of the common lady-bird (*Coccinella semptem-punctata*), which feed upon them †.

It is remarkable, says Kirby, that many of the insects which are occasionally observed to emigrate, as, for instance, the libellulæ, coccinellæ, carabi, cicadæ, &c., are not usually social insects, but seem to congregate, like swallows, merely for the purpose of emigration ‡. Here, therefore, we have an example of an instinct developing itself on certain rare emergencies, causing unsocial species to become gregarious, and to venture sometimes even to cross the ocean.

Diffused by winds and currents.—To the armies of locusts darkening the air in Africa, and traversing the globe from Turkey to our southern counties in England, we need not here allude. When the western gales sweep over the Pampas, they bear along with them myriads of insects of various kinds. As a proof of the manner in which species may be thus diffused,

* Description of the Equatorial Regions—Malte-Brun, vol. v. p. 379.

† Kirby and Spence, vol. ii. p. 9, 1817. ‡ Ibid., p. 12.

we may mention that when the Creole frigate was lying in the outer roads off Buenos Ayres, in 1819, at the distance of six miles from the land, her decks and rigging were suddenly covered with thousands of flies and grains of sand. The sides of the vessel had just received a fresh coat of paint, to which the insects adhered in such numbers as to spot and disfigure the vessel, and to render it necessary partially to renew the paint *. Captain W. H. Smyth was obliged to repaint his vessel, the Adventure, in the Mediterranean, from the same cause. He was on his way from Malta to Tripoli, when a southern wind blowing from the coast of Africa, then one hundred miles distant, drove such myriads of flies upon the fresh paint, that not the smallest point was left unoccupied by insects.

To the southward of the river Plate, off Cape St. Antonio, and at the distance of fifty miles from land, several large dragon-flies alighted on the Adventure frigate, during Captain King's late expedition to the Straits of Magellan. If the wind abates when insects are thus crossing the sea, the most delicate species are not necessarily drowned, for many can repose without sinking on the unruffled surface of the deep. The slender long-legged tipulæ have been seen standing on the surface of the sea, when driven out far from our coast, and took wing immediately on being approached †. Exotic beetles are sometimes thrown on our shore, which revive after having been long drenched in salt-water; and the periodical appearance of some conspicuous butterflies amongst us, after being unseen for five or fifty years, has been ascribed, not without probability, to the agency of the winds.

By rivers, animals and birds.—Inundations of rivers, observes Kirby, if they happen at any season except in the depth of winter, always carry down a number of insects, floating on the surface of bits of stick, weeds, &c., so that when the waters subside, the entomologist may generally reap a plentiful har-

* I am indebted to Lieutenant Graves, R. N., for this information.

† I state this fact on the authority of my friend, Mr. John Curtis.

vest. In the dissemination, moreover, of these minute beings, as in that of plants, the larger animals play their part. Insects are, in numberless instances, borne along in the coats of animals, or the feathers of birds; and the eggs of some species are capable, like seeds, of resisting the digestive powers of the stomach, and after they are swallowed with herbage, may be ejected again unharmed in the dung.

Geographical Distribution and Diffusion of Man.

We have reserved for the last our observations on the range and diffusion of the human species over the earth, and the influence of man, in spreading other animals and plants, especially the terrestrial.

Speculations as to the birth-place of the human species.—Many naturalists have amused themselves in speculating on the probable birth-place of mankind, the point from which, if we assume the whole human race to have descended from a single pair, the tide of emigration must originally have proceeded. It has been always a favourite conjecture, that this birth-place was situated within or near the tropics, where perpetual summer reigns, and where fruits, herbs, and roots are plentifully supplied throughout the year. The climate of these regions, it has been said, is suited to a being born without any covering, and who had not yet acquired the arts of building habitations or providing clothes.

Progress of human population.—'The hunter state,' it has been argued, 'which Montesquieu placed the first, was probably only the second stage to which mankind arrived, since so many arts must have been invented to catch a salmon or a deer, that society could no longer have been in its infancy when they came into use *.' When regions where the spontaneous fruits of the earth abound became overpeopled, men would naturally diffuse themselves over the neighbouring parts of the temperate one; but a considerable time would probably elapse before this event took place; and it is possible, as a writer before

* Brand's Select Dissert. from the Amœn. Acad., vol. i. p. 118.

cited observes, that in the interval before the multiplication of their numbers and their increasing wants had compelled them to emigrate, some arts to take animals were invented, but far inferior to what we see practiced at this day among savages. As their habitations gradually advanced into the temperate zone, the new difficulties they had to encounter would call forth by degrees the spirit of invention, and the probability of such inventions always rises with the number of people involved in the same necessity *.

A distinguished modern writer, who coincides for the most part in the views above mentioned, has introduced one of the persons in his second dialogue as objecting to the theory of the human race having gradually advanced from a savage to a civilized state, on the ground that 'the first man must have inevitably been destroyed by the elements or devoured by savage beasts, so infinitely his superiors in physical force †. He then contends against the difficulty here started by various arguments, all of which were, perhaps, superfluous, for if a philosopher is pleased to indulge in conjectures on this subject, why should he not assign, as the original seat of man, some one of those large islands within the tropics, which are as free from wild beasts as Van Diemen's Land or Australia? Here man may have remained for a period peculiar to a single isle, just as some of the large anthropomorphous species are now limited to one island within the tropics. In such a situation, the new-born race might have lived in security, though far more helpless than the New Holland savages, and might have found abundance of vegetable food. Colonies may afterwards have been sent forth from this mother country, and then the peopling of the earth may have proceeded according to the hypothesis before alluded to.

In an early stage of society the necessity of hunting acts as a principle of repulsion, causing men to spread with the greatest rapidity over a country until the whole is covered

* Brand's Select Dissert. from the Amœn. Acad., vol. i. p. 118.

† Sir H. Davy, Consolations in Travel, p. 74.

with scattered settlements. It has been calculated that eight hundred acres of hunting-ground only produce as much food as half an acre of arable land. When the game has been in a great measure exhausted, and a state of pasturage succeeds, the several hunter tribes, being already scattered, may multiply in a short time into the greatest number which the pastoral state is capable of sustaining. The necessity, says Brand, thus imposed upon the two savage states, of dispersing themselves far and wide over the country, affords a reason why, at a very early period, the worst parts of the earth may have become inhabited.

But this reason, it may be said, is only applicable in as far as regards the peopling of a continuous continent; whereas the smallest islands, however remote from continents, have almost invariably been found inhabited by man. St. Helena, it is true, afforded an exception; for when that island was discovered in 1501, it was only inhabited by sea-fowl, and occasionally by seals and turtles, and was covered with a forest of trees and shrubs, all of species peculiar, as we before observed, with one or two exceptions, and which seem to have been expressly created for this remote and insulated spot.

Drifting of canoes to vast distances.—But very few of the numerous coral islets and volcanos of the vast Pacific, capable of sustaining a few families of men, have been found untenanted; and we have, therefore, to inquire whence and by what means, if all the members of the great human family have had one common source, could those savages have migrated. Cook, Forster, and others, have remarked that parties of savages in their canoes must often have lost their way and must have been driven on distant shores, where they were forced to remain, deprived both of the means and of the requisite intelligence for returning to their own country. Thus Captain Cook found on the island of Wateoo, three inhabitants of Otaheite, who had been drifted thither in a canoe, although the distance between the two isles is five hundred and fifty miles. In 1696, two canoes, containing thirty persons, who

had left Ancorso, were thrown by contrary winds and storms on the island of Samar, one of the Philippines, at a distance of eight hundred miles. In 1721, two canoes, one of which contained twenty-four, and the other six persons, men, women, and children, were drifted from an island called Baroilep, to the island of Guam, one of the Marians *.

Kotzebue, when investigating the Coral isles of Radack, at the eastern extremity of the Caroline isles, became acquainted with a person of the name of Kadu, who was a native of Ulea, an isle fifteen hundred miles distant, from which he had been drifted with a party. Kadu and three of his countrymen, one day left Ulea in a sailing boat, when a violent storm arose, and drove them out of their course; they drifted about the open sea for eight months, according to their reckoning by the moon, making a knot on a cord at every new moon. Being expert fishermen, they subsisted entirely on the produce of the sea; and when the rain fell, laid in as much fresh water as they had vessels to contain it. 'Kadu,' says Kotzebue, 'who was the best diver, frequently went down to the bottom of the sea, where it is well known that the water is not so salt, with a cocoa-nut shell, with only a small opening.' When these unfortunate men reached the isles of Radack, every hope and almost every feeling had died within them; their sail had long been destroyed, their canoe had long been the sport of winds and waves, and they were picked up by the inhabitants of Aur, in a state of insensibility †; but by the hospitable care of those islanders they soon recovered, and were restored to perfect health.

Captain Beechey, in his late voyage to the Pacific, fell in with some natives of the Coral Islands, who had in a similar manner been carried to a great distance from their native country. They had embarked to the number of one hundred and fifty souls, in three double canoes, from Anaa, or Chain Island, situate about three hundred miles to the eastward of Otaheite. They were overtaken by the monsoon, which dis-

* Malte-Brun's Geography, vol. iii. p. 419.

† Kotzebue's Voyage, 1815—1818. Quarterly Review, vol. xxvi. p. 361.

persed the canoes, and, after driving them about the ocean, left them becalmed, so that a great number of persons perished. Two of the canoes were never heard of, but the other was drifted from one uninhabited island to another, at each of which the voyagers obtained a few provisions; and at length, after having wandered for a distance of six hundred miles, they were found and carried to their home in the Blossom *.

The space traversed in some of these instances was so great, that similar accidents might suffice to transport canoes from various parts of Africa to the shores of South America, or from Spain to the Azores, and thence to North America. So that man, even in a rude state of society, is liable to be scattered involuntarily by the winds and waves over the globe, in a manner singularly analogous to that in which many plants and animals are diffused. We ought not, then, to wonder that during the ages required for some tribes of the human race to attain that advanced stage of civilization which empowers the navigator to cross the ocean in all directions with security, the whole earth should have become the abode of rude tribes of hunters and fishers. Were the whole of mankind now cut off, with the exception of one family, inhabiting the old or new continent, or Australia, or even some coral islet of the Pacific, we should expect their descendants, though they should never become more enlightened than the South Sea Islanders or the Esquimaux, to spread in the course of ages over the whole earth, diffused partly by the tendency of population to increase beyond the means of subsistence, in a limited district, and partly by the accidental drifting of canoes by tides and currents to distant shores.

Involuntary influence of Man in diffusing Animals and Plants.

Many of the general remarks which we made respecting the influence of man in spreading or in checking the diffusion of

* Narrative of a Voyage to the Pacific, &c., in the years 1825, 1826, 1827, 1828, p. 170.

plants apply equally to his relations with the animal kingdom. We shall be led on a future occasion to speak of the instrumentality of our species in naturalizing useful animals and plants in new regions, when we explain our views of the effects which the spreading and increase of certain species exert in the extirpation of others. At present we shall confine ourselves to a few remarks on the involuntary aid which man lends to the dissemination of species.

In the mammiferous class our influence is chiefly displayed in increasing the number of quadrupeds which are serviceable to us, and in exterminating or reducing the number of those which are noxious.

Sometimes, however, we unintentionally promote the multiplication of inimical species, as when we introduced the rat, which was not indigenous in the New World, into all parts of America. They have been conveyed over in ships, and now infest a great multitude of islands and parts of that continent. In like manner the Norway rat has been imported into England, where it plunders our property in ships and houses.

The great viper (fer de lance), a species no less venomous than the rattle-snake, which now ravages Martinique and St. Lucia, was accidentally introduced by man, and exists in no other part of the West Indies.

Many parasitic insects, which attack our persons, and some of which are supposed to be peculiar to our species, have been carried into all parts of the earth, and have as high a claim as man to an *universal* geographical distribution.

A great variety of insects have been transported in ships from one country to another, especially in warmer latitudes. Notwithstanding the coldness of our climate, we have been unable to prevent the cockroach (*Blatta orientalis*) from entering and diffusing itself in our ovens and kneading troughs, and availing itself of the artificial warmth which we afford. It is well known also that beetles, and many other kinds of ligniperdous insects, have been introduced into Great Britain in timber; especially several North American species. 'The

commercial relations,' says Malte-Brun*, 'between France and India, have transported from the latter country the aphis, which destroys the apple-tree, and two sorts of Neuroptera, the *lucifuga* and *flavicola,* mostly confined to Provence and the neighbourhood of Bordeaux, where they devour the timber in the houses and naval arsenals.'

Among molluscs we may mention the *teredo navalis,* which is a native of equatorial seas, but which, by adhering to the bottom of ships, was transported to Holland, where it has been most destructive to vessels and piles. The same species has also become naturalized in England, and other countries enjoying an extensive commerce. *Bulimus undatus,* a land species of considerable size, native of Jamaica and other West Indian islands, has been imported, adhering to tropical timber, into Liverpool, and is now naturalized in the woods near that town †.

In all these and innumerable other instances we may regard the involuntary agency of man as strictly analogous to that of the inferior animals. Like them, we unconsciously contribute to extend or limit the geographical range and numbers of certain species, in obedience to general rules in the economy of nature, which are for the most part beyond our control.

* Syst. of Geog., vol. viii. p. 169.

† On the authority of Mr. Broderip.

CHAPTER VIII.

Theories respecting the original introduction of species—Proposal of an hypothesis on this subject—Supposed centres or foci of creation—Why the distinct provinces of animals and plants have not become more blended together—Brocchi's speculations on the loss of species—Stations of plants and animals—Complication of causes on which they depend—Stations of plants, how affected by animals—Equilibrium in the number of species, how preserved—Peculiar efficacy of insects in this task—Rapidity with which certain insects multiply or decrease in numbers—Effect of omnivorous animals in preserving the equilibrium of species—Reciprocal influence of aquatic and terrestrial species on each other.

THEORIES RESPECTING THE ORIGINAL INTRODUCTION OF SPECIES.

Theory of Linnæus.—It would be superfluous to examine the various attempts which were made to explain the phenomena of the distribution of species alluded to in the preceding chapters, in the infancy of the sciences of botany, zoology, and physical geography. The theories or rather conjectures then indulged now stand refuted by a simple statement of facts; and if Linnæus were living, he would be the first to renounce the notions which he promulgated. For he imagined the habitable world to have been for a certain time limited to one small tract, the only portion of the earth's surface that was as yet laid bare by the subsidence of the primæval ocean. In this fertile spot he supposed the originals of all the species of plants which exist on this globe to have been congregated, together with the first ancestors of all animals and of the human race. 'In quâ commodè habitaverint animalia omnia, et vegetabilia lætè germinaverint.' In order to accommodate the various habitudes of so many creatures, and to provide a diversity of climate suited to their several natures, the tract in which the creation took place was supposed to have been situated in some warm region of the earth, but to have contained a lofty mountain range, on the heights and in the declivities of which were

to be found all temperatures and every clime, from the torrid to the frozen zone *.

That there never was a universal ocean since the planet was inhabited, or rather since the oldest groups of strata yet known to contain organic remains were formed, is proved by the presence of terrestrial plants in all the older formations; and if this conclusion was not established, yet no geologist could deny that, since the first small portion of the earth was laid dry, there have been many entire changes in the species of plants and animals inhabiting the land.

Proposal of an hypothesis on this subject.—But without dwelling on the above and other refuted theories, let us inquire whether we can substitute some hypothesis as simple as that of Linnæus, to which the phenomena now ascertained in regard to the distribution both of aquatic and terrestrial species may be referred. The following may, perhaps, be reconcileable with known facts:—Each species may have had its origin in a single pair, or individual, where an individual was sufficient, and species may have been created in succession at such times and in such places as to enable them to multiply and endure for an appointed period, and occupy an appointed space on the globe.

In order to explain this theory, let us suppose every living thing to be destroyed in the western hemisphere, both on the land and in the ocean, and permission to be given to man to people this great desert, by transporting into it animals and plants from the eastern hemisphere, a strict prohibition being enforced against introducing two original stocks of the same species.

Now the result we conceive of such a mode of colonizing would correspond exactly, so far as regards the grouping of animals and plants, with that now observed throughout the globe. It would be necessary for naturalists, before they imported species into particular localities, to study attentively

* De terra habitabili incremento; also Prichard, Phys. Hist. of Mankind, vol. i. p. 17, where the hypotheses of different naturalists are enumerated.

the climate and other physical conditions of each spot. It would be no less requisite to introduce the different species in succession, so that each plant and animal might have time and opportunity to multiply before the species destined to prey upon it was admitted. Many herbs and shrubs, for example, must spread far and wide before the sheep, the deer, and the goat could be allowed to enter, lest they should devour and annihilate the original stocks of many plants, and then perish themselves for want of food. The above-mentioned herbivorous animals in their turn must be permitted to make considerable progress before the entrance of the first pair of wolves or lions. Insects must be allowed to swarm before the swallow could be permitted to skim through the air and feast on thousands at one repast.

It is evident that, however equally in this case our original stocks were distributed over the whole surface of land and water, there would nevertheless arise distinct botanical and zoological provinces, for there are a great many natural barriers which oppose common obstacles to the advance of a variety of species. Thus, for example, almost all the animals and plants naturalized by us towards the extremity of South America, would be unable to spread beyond a certain limit, towards the east, west, and south, because they would be stopped by the ocean, and a few of them only would succeed in reaching the cooler latitudes of the northern hemisphere, because they would be incapable of bearing the heat of the tropics, through which they must pass. In the course of ages, undoubtedly, exceptions would arise, and some species might become common to the temperate and polar regions, or both sides of the equator; for we have before shown that the powers of diffusion conferred on some classes are very great. But we should confidently predict that these exceptions would never become so numerous as to invalidate the general rule.

Some of the plants and animals transplanted by us to the coast of Chili or Peru would never be able to cross the Andes, so as to reach the Eastern plains; nor, for a similar reason,

would those first established in the Pampas, or the valleys of the Amazon and the Orinoco, ever arrive at the shores of the Pacific.

In the ocean an analogous state of things would prevail; for there, also, climate would exert a great influence in limiting the range of species, and the land would stop the migrations of aquatic tribes as effectually as the sea arrests the dispersion of the terrestrial. As certain birds, insects, and the seeds of plants, can never cross the direction of prevailing winds, so currents form natural barriers to the dissemination of many oceanic races. A line of shoals may be as impassable to pelagian species, as are the Alps and the Andes to plants and animals peculiar to plains; while deep abysses may prove insuperable obstacles to the migrations of the inhabitants of shallow waters.

Supposed centres, or foci, of creation.—It is worthy of observation, that one effect of the introduction of single pairs of each species must be the confined range of certain groups in spots which, like small islands, or solitary inland lakes, have few means of interchanging their inhabitants with adjoining regions. Now this congregating, in a small space, of many peculiar species, would give an appearance of *centres*, or *foci*, of creation, as they have been termed, as if there were favourite points where the creative energy has been in greater action than in others, and where the numbers of peculiar organic beings have consequently become more considerable.

We do not mean to call in question the soundness of the inferences of some botanists, as to the former existence of certain limited spots whence species of plants have been propagated, radiating, as it were, in all directions from a common centre. On the contrary, we conceive these phenomena to be the necessary consequences of the plan of nature before suggested, operating during the successive mutations of the surface, some of which the geologist can prove to have taken place subsequently to the period when many species now existing were created. In order to exemplify how this arrangement of

plants may have been produced, let us imagine that, about three centuries before the discovery of St. Helena (itself of submarine volcanic origin), a multitude of new isles had been thrown up in the surrounding sea, and that these had each become clothed with plants emigrating from St. Helena, in the same manner as the wild plants of Campania have diffused themselves over Monte Nuovo. Whenever the first botanist investigated the new archipelago, he would, in all probability, find a different assemblage of plants in each of the isles of recent formation; but in St. Helena itself, he would meet with individuals of every species belonging to all parts of the archipelago, and some, in addition, peculiar to itself, viz., those which had not been able to obtain a passage into any one of the surrounding new-formed lands. In this case, it might be truly said that the original isle was the primitive focus, or centre, of a certain type of vegetation, whereas, in the surrounding isles, there would be a smaller number of species, yet all belonging to the same group.

But this peculiar distribution of plants would not warrant the conclusion that, in the space occupied by St. Helena, there had been a greater exertion of creative power than in the spaces of equal area occupied by the new adjacent lands, because, within the period in which St. Helena had acquired its peculiar vegetation, each of the spots supposed to be subsequently converted into land, may have been the birth-places of a great number of *marine* animals and plants, which may have had time to scatter themselves far and wide over the southern Atlantic.

Why distinct provinces have not been more blended.—Perhaps it may be objected to some parts of the foregoing train of reasoning, that during the lapse of past ages, especially during many partial revolutions of the globe of comparatively modern date, different zoological and botanical provinces ought to have become more confounded and blended together—that the distribution of species approaches too nearly to what might have been expected, if animals and plants had been introduced into

the globe when its physical geography had already assumed the features which it now wears; whereas we know that, in certain districts, considerable geographical changes have taken place since species identical with those now in being were created.

Brocchi's speculations on the loss of species.—These, and many kindred topics, cannot be fully discussed until we have considered, not merely the general laws which may regulate the first introduction of species, but those which may limit their *duration* on the earth. Brocchi, whose untimely death in Egypt is deplored by all who have the progress of geology at heart, has remarked, when hazarding some interesting conjectures respecting 'the loss of species,' that a modern naturalist had no small assurance, who declared 'that individuals alone were capable of destruction, and that species were so perpetuated that nature could not annihilate them, so long as the planet lasted, or at least that nothing less than the shock of a comet, or some similar disaster, could put an end to their existence *.' The Italian geologist, on the contrary, had satisfied himself, that many species of testacea, which formerly inhabited the Mediterranean, had become extinct, although a great number of others, which had been the contemporaries of those lost races, still survived. He came to the opinion, that about half the species which peopled the waters when the Subapennine strata were deposited, had gone out of existence; and in this inference he does not appear to have been far wrong.

But instead of seeking a solution of this problem, like some other geologists of his time, in a violent and general catastrophe, Brocchi endeavoured to imagine some regular and constant law by which species might be made to disappear from the earth gradually and in succession. The death, he suggested, of a species might depend, like that of individuals, on certain peculiarities of constitution conferred upon them at their birth, and as the longevity of the one depends on a cer-

* Necker, Phytozool. Philosoph., p. 21. Brocchi, Conch. Foss. Subap., tome i. p. 229.

tain force of vitality, which, after a period, grows weaker and weaker, so the duration of the other may be governed by the quantity of prolific power bestowed upon the species, which, after a season, may decline in energy, so that the fecundity and multiplication of individuals may be gradually lessened from century to century, 'until that fatal term arrives, when the embryo, incapable of extending and developing itself, abandons, almost at the instant of its formation, the slender principle of life by which it was scarcely animated,—and so all dies with it.'

Now we might coincide in opinion with the Italian naturalist, as to the gradual extinction of species one after another, by the operation of regular and constant causes, without admitting an inherent principle of deterioration in their physiological attributes. We might concede 'that many species are on the decline, and that the day is not far distant when they will cease to exist;' yet deem it consistent with what we know of the nature of organic beings, to believe that the last individuals of each species retain their prolific powers in their full intensity.

Brocchi has himself speculated on the share which a change of climate may have had in rendering the Mediterranean unfit for the habitation of certain testacea, which still continued to thrive in the Indian ocean, and of others which were now only represented by analogous forms within the tropics. He must also have been aware that other extrinsic causes, such as the progress of human population, or the increase of some one of the inferior animals, might gradually lead to the extirpation of a particular species, although its fecundity might remain to the last unimpaired. If, therefore, amid the vicissitudes of the animate and inanimate world, there are known causes capable of bringing about the decline and extirpation of species, it became him thoroughly to investigate the full extent to which these might operate, before he speculated on any cause of so purely hypothetical a kind, as 'the diminution of the prolific virtue.'

If it could have been shown that some wild plant had

insensibly dwindled away and died out, as sometimes happens to cultivated varieties propagated by cuttings, even though climate, soil, and every other circumstance should continue identically the same—if any animal had perished while the physical condition of the earth, and the number and force of its foes, with every other extrinsic cause, remained unaltered, then might we have some ground for suspecting that the infirmities of age creep on as naturally on species as upon individuals. But in the absence of such observations, let us turn to another class of facts, and examine attentively the circumstances which determine the *stations* of particular animals and plants, and perhaps we shall discover, in the vicissitudes to which these stations are exposed, a cause fully adequate to explain the phenomena under consideration.

Stations of plants and animals.—Stations comprehend all the circumstances, whether relating to the animate or inanimate world, which determine whether a given plant or animal can exist in a given locality, so that if it be shown that stations can become essentially modified by the influence of known causes, it will follow that species, as well as individuals, are mortal.

Every naturalist is familiar with the fact, that although in a particular country, such as Great Britain, there may be more than three thousand species of plants, ten thousand insects, and a great variety in each of the other classes, yet there will not be more than a hundred, perhaps not half that number, inhabiting any given locality. There may be no want of space in the supposed tract; it may be a large mountain, or an extensive moor, or a great river-plain, containing room enough for individuals of every species in our island; yet the spot will be occupied by a few to the exclusion of many, and these few are enabled, throughout long periods, to maintain their ground successfully against every intruder, notwithstanding the facilities which species enjoy, by virtue of their powers of diffusion, of invading adjacent territories.

The principal causes which enable a certain assemblage of

plants thus to maintain their ground against all others depend, as is well known, on the relations between the physiological nature of each species, and the climate, exposure, soil, and other physical conditions of the locality. Some plants live only on rocks, others in meadows, a third class in marshes. Of the latter, some delight in a fresh-water morass,—others in salt marshes, where their roots may copiously absorb saline particles. Some prefer an alpine region in a warm latitude, where, during the heat of summer, they are constantly irrigated by the cool waters of melting snows. To others loose sand, so fatal to the generality of species, affords the most proper station. The *Carex arenaria* and the *Elymus arenarius* acquire their full vigour on a sandy dune, obtaining an ascendency over the very plants which in a stiff clay would immediately stifle them.

Where the soil of a district is of so peculiar a nature that it is extremely favourable to certain species, and agrees ill with every other, the former get exclusive possession of the ground, and, as in the case of heaths, live in societies. In like manner the Bog moss (*Sphagnum palustrë*) is fully developed in peaty swamps, and becomes, like the heath, in the language of botanists, a social plant. Such monopolies, however, are not common, for they are checked by various causes. Not only are many species endowed with equal powers to obtain and keep possession of similar stations, but each plant, for reasons not fully explained by the physiologist, has the property of rendering the soil where it has grown less fitted for the support of other individuals of its own species, or even other species of the same family. Yet the same spot, so far from being impoverished, is improved, for plants of *another* family. Animals also interfere most actively to preserve an equilibrium in the vegetable kingdom.

Equilibrium in the number of species, how preserved.—'All the plants of a given country,' says De Candolle, in his usual spirited style, 'are at war one with another. The first which establish themselves by chance in a particular spot, tend, by

the mere occupancy of space, to exclude other species—the greater choke the smaller, the longest livers replace those which last for a shorter period, the more prolific gradually make themselves masters of the ground, which species multiplying more slowly would otherwise fill.'

In this continual strife, it is not always the resources of the plant itself which enable it to maintain or extend its ground. Its success depends, in a great measure, on the number of its foes or allies, among the animals and plants inhabiting the same region. Thus, for example, a herb which loves the shade may multiply, if some tree with spreading boughs and dense foliage flourish in the neighbourhood. Another, which, if unassisted, would be overpowered by the rank growth of some hardy competitor, is secure, because its leaves are unpalatable to cattle, which, on the other hand, annually crop down its antagonist, and rarely suffer it to ripen its seed.

Oftentimes we see some herb which has flowered in the midst of a thorny shrub, when all the other individuals of the same species, in the sunny fields around, are eaten down, and cannot bring their seed to maturity. In this case, the shrub has lent his armour of spines and prickles to protect the defenceless herb against the mouths of the cattle; and thus a few individuals which occupied, perhaps, the most unfavourable station in regard to exposure, soil, and other circumstances, may nevertheless, by the aid of an ally, become the principal source whereby the winds are supplied with seeds which perpetuate the species throughout the surrounding tract.

In the above example we see one plant shielding another from the attacks of animals; but instances are, perhaps, still more numerous, where some animal defends a plant against the enmity of some other subject of the vegetable kingdom.

Scarcely any beast, observes a Swedish naturalist *, will touch the nettle, but fifty different kinds of insects are fed by it. Some of these seize upon the root, others upon the stem; some eat the leaves, others devour the seeds and flowers: but

* Amœn. Acad. vol. vi., p. 17, § 12.

for this multitude of enemies, the nettle would annihilate a great number of plants. Linnæus tells us, in his Tour in Scania, that goats were turned into an island which abounded with the *Agrostis arundinacea*, where they perished by famine; but horses which followed them, grew fat on the same plant. The goat, also, he says, thrives on the meadow-sweet and water-hemlock, plants which are injurious to cattle *.

Every plant, observes Wilcke, has its proper insect allotted to it to curb its luxuriancy, and to prevent it from multiplying to the exclusion of others. 'Thus grass in meadows sometimes flourishes so as to exclude all other plants: here the Phalæna graminis (*Bombyx gram.*), with her numerous progeny, find a well-spread table; they multiply in immense numbers, and the farmer for some years laments the failure of his hay crop; but the grass being consumed, the moths die with hunger, or remove to another place. Now the quantity of grass being greatly diminished, the other plants, which were before choked by it, spring up, and the ground becomes variegated with a multitude of different species of flowers. Had not nature given a commission to this minister for that purpose, the grass would destroy a great number of species of vegetables, of which the equilibrium is now kept up †.'

In the above passage allusion is made to the ravages committed in 1740 and the two following years in many provinces of Sweden, by a most destructive insect. The same moth is said never to touch the fox-tail grass ‡, so that it may be classed as a most active ally and benefactor of that species, and as peculiarly instrumental in preserving it in its present abundance. A discovery of Rolander, cited in the treatise of Wilcke above-mentioned, affords a good illustration of the checks and counterchecks which nature has appointed to preserve the balance of power amongst species. 'The Phalæna strobilella has the fir cone assigned to it to deposit its eggs upon; the young caterpillars coming out of the shell consume

* Amœn. Acad., vol. vii. p. 409. † Ibid., vol. vi., p. 17, § 11 and 12.

‡ Kirby and Spence, vol. i. p. 178.

the cone and superfluous seed; but lest the destruction should be too general, the Ichneumon strobilellæ lays its eggs in the caterpillar, inserting its long tail in the openings of the cone till it touches the included insect, for its body is too large to enter. Thus it fixes its minute egg upon the caterpillar, which being hatched destroys it *.'

Agency of insects.—Entomologists enumerate many parallel cases where insects, appropriated to certain plants, are kept down by other insects, and these again by parasites expressly appointed to prey on them †. Few, perhaps, are in the habit of duly appreciating the extent to which insects are active in preserving the balance of species among plants, and thus regulating indirectly the relative numbers of many of the higher orders of terrestrial animals.

The peculiarity of their agency consists in their power of suddenly multiplying their numbers to a degree which could only be accomplished in a considerable lapse of time in any of the larger animals, and then as instantaneously relapsing without the intervention of any violent disturbing cause, into their former insignificance.

If, for the sake of employing, on different but rare occasions, a power of many hundred horses, we were under the necessity of feeding all these animals at great cost in the intervals when their services were not required, we should greatly admire the invention of a machine, such as the steam-engine, which was capable at any moment of exerting the same degree of strength without any consumption of food during periods of inaction. The same kind of admiration is strongly excited when we contemplate the powers of insect life, in the creation of which nature has been so prodigal. A scanty number of minute individuals, only to be detected by careful research, are ready in a few days, weeks, or months, to give birth to myriads which may repress any degree of monopoly in another species, or remove nuisances, such as dead carcasses, which might taint the air. But no sooner has the destroying commission been

* Amœn. Acad., vol. vi. § 14. † Kirby and Spence, vol. iv. p. 218.

executed than the gigantic power becomes dormant—each of the mighty host soon reaches the term of its transient existence, and the season arrives when the whole species passes naturally into the egg, and thence into the larva and pupa state. In this defenceless condition it may be destroyed either by the elements, or by the augmentation of some of its numerous foes which may prey upon it in these stages of its transformation; or it often happens that in the following year the season proves unfavourable to the hatching of the eggs or the development of the pupæ.

Thus the swarming myriads depart which may have covered the vegetation like the aphides, or darkened the air like locusts. In almost every season there are some species which in this manner put forth their strength, and then, like Milton's spirits which thronged the spacious hall, 'reduce to smallest forms their shapes immense'—

> ——————— So thick the aëry crowd
> Swarm'd and were straiten'd; till, the signal given,
> Behold a wonder! they but now who seem'd
> In bigness to surpass earth's giant sons,
> Now less than smallest dwarfs.

A few examples will illustrate the mode in which this force operates. It is well known that, among the countless species of the insect creation, some feed on animal, others on vegetable matter, and, upon considering a catalogue of 8000 British insects and arachnidæ, Mr. Kirby found that these two divisions were nearly a counterpoise to each other, the carnivorous being somewhat preponderant. There are also distinct species, some appointed to consume living, others dead or putrid animal and vegetable substances. One female, of *Musca carnaria*, will give birth to 20,000 young; and the larvæ of many flesh-flies devour so much food in twenty-four hours, and grow so quickly, as to increase their weight two hundred-fold! In five days after being hatched they arrive at their full growth and size, so that there was ground, says Kirby, for the assertion of Linnæus, that three flies of M. vomitoria

could devour a dead horse as quickly as a lion *; and another Swedish naturalist remarks, that so great are the powers of propagation of a single species, even of the smallest insects, that each can commit, when required, more ravages than the elephant †.

Next to locusts, the aphides, perhaps, exert the greatest power over the vegetable world, and, like them, are sometimes so numerous as to darken the air. The multiplication of these little creatures is without parallel, and almost every plant has its peculiar species. Reaumur has proved that in five generations one aphis may be the progenitor of 5,904,900,000 descendants; and it is supposed that in one year there may be twenty generations ‡. Mr. Curtis § observes that, as among caterpillars we find some that are constantly and unalterably attached to one or more particular species of plants, and others that feed indiscriminately on most sorts of herbage, so it is precisely with the aphides; some are particular, others more general feeders; and as they resemble other insects in this respect, so they do also in being more abundant in some years than others. In 1793 they were the chief, and in 1798 the sole cause of the failure of the hops. In 1794, a season almost unparalleled for drought, the hop was perfectly free from them, while peas and beans, especially the former, suffered very much from their depredations.

The ravages of the caterpillars of some of our smaller moths afford a good illustration of the temporary increase of a species. The oak-trees of a considerable wood have been stripped of their leaves as bare as in winter, by the caterpillars of a small green moth (*Tortrix irridana*), which has been observed the year following not to abound ‖. The Gamma moth (*Plusia gamma*), although one of our common species, is not dreaded by us for its devastations, but legions of their caterpillars have at times created alarm in France, as in 1735. Reaumur

* Kirby and Spence, vol. i. p. 250. † Wilcke, Amœn. Acad., chap. ii.

‡ Kirby and Spence, vol. i. p. 174. § Trans. Linn. Soc., vol. vi.

‖ Lib. Ent. Know., Insect Trans., p. 203. See Haworth Lep.

observes that the female moth lays about 400 eggs; so that if twenty caterpillars were distributed in a garden, and all lived through the winter and became moths in the succeeding May, the eggs laid by these, if all fertile, would produce 800,000 *. A modern writer, therefore, justly observes that, did not Providence put causes in operation to keep them in due bounds, the caterpillars of this moth alone, leaving out of consideration the 2000 other British species, would soon destroy more than half of our vegetation †.

In the latter part of the last century an ant, most destructive to the sugar-cane (*Formica saccharivora*), appeared in such infinite hosts in the island of Grenada, as to put a stop to the cultivation of that vegetable. Their numbers were incredible. The plantations and roads were filled with them; many domestic quadrupeds, together with rats, mice, and reptiles, and even birds, perished in consequence of this plague. It was not till 1780 that they were at length annihilated by torrents of rain, which accompanied a dreadful hurricane ‡.

Devastations caused by Locusts.—We may conclude by mentioning some instances of the devastations of locusts in various countries. Among other parts of Africa, Cyrenaica has been at different periods infested by myriads of these creatures, which have consumed nearly every green thing. The effect of the havoc committed by them may be estimated by the famine they occasioned. St. Augustin mentions a plague of this kind in Africa which destroyed no less than eight hundred thousand men in the kingdom of Masanissa alone, and many more upon the territories bordering upon the sea. It is also related, that in the year 591 an infinite army of locusts migrated from Africa into Italy, and, after grievously ravaging the country, were cast into the sea, when there arose a pestilence from their stench which carried off nearly a million of men and beasts.

In the Venetian territory, also, in 1478, more than thirty

* Reaumur, ii. 237. † Lib. Ent. Know., Insect Trans., p. 212.

‡ Kirby and Spence, vol. i. p. 183. Castle, Phil. Trans., xxx. 346.

thousand persons are said to have perished in a famine, occasioned by this scourge; and other instances are recorded of their devastations in France, Spain, Italy, Germany, &c. In different parts of Russia also, Hungary, and Poland,—in Arabia and India, and other countries, their visitations have been periodically experienced. Although they have a preference for certain plants, yet, when these are consumed, they will attack almost all the remainder. In the accounts of the invasions of locusts, the statements which appear most marvellous relate to the prodigious mass of matter which encumbers the sea wherever they are blown into it, and the pestilence arising from its putrefaction. Their dead bodies are said to have been, in some places, heaped one upon another, to the depth of four feet, in Russia, Poland, and Lithuania; and when, in southern Africa, they were driven into the sea by a north-west wind, they formed, says Barrow, along the shore, for fifty miles, a bank three or four feet high *. But when we consider that forests are stripped of their foliage, and the earth of its green garment, for thousands of square miles, it may well be supposed that the volume of animal matter produced may equal that of great herds of quadrupeds and flights of large birds suddenly precipitated into the sea.

The occurrence of such events at certain intervals, in hot countries, like the severe winters and damp summers returning after a series of years in the temperate zone, affect the proportional numbers of almost all classes of animals and plants, and are probably fatal to the existence of many which would otherwise thrive there, while, on the contrary, they must be favourable to certain species which, if deprived of such aid, might not maintain their ground.

Although it may usually be remarked that the extraordinary increase of some one species is immediately followed and checked by the multiplication of another, yet this is not always the case, partly because many species feed in common on the same kinds of food, and partly because many kinds of food are

* Travels in Africa, p. 257. Kirby and Spence, vol. i. p. 215.

often consumed indifferently by one and the same species. In the former case, where a variety of different animals have precisely the same taste, as, for example, when many insectivorous birds and reptiles devour alike some particular fly or beetle, the unusual numbers of the latter may only cause a slight and almost imperceptible augmentation of each of those species of bird and reptile. In the other instance, where one animal preys on others of almost every class, as, for example, where our English buzzards devour not only small quadrupeds, as rabbits and field-mice, but also birds, frogs, lizards, and insects, the profusion of any one of these last may cause all such general feeders to subsist more exclusively upon the species thus in excess, and the balance may thus be restored.

Effect of omnivorous animals in preserving the equilibrium of species.—The number of species which are nearly omnivorous is considerable; and although every animal has, perhaps, a predilection for some one description of food rather than another, yet some are not even confined to one of the great kingdoms of the organic world. Thus when the racoon of the West Indies can neither procure fowls, fish, snails, nor insects, it will attack the sugar-canes, and devour various kinds of grain. The civets, when animal food is scarce, maintain themselves on fruits and roots.

Numerous birds, which feed indiscriminately on insects and plants, are perhaps more instrumental than any other of the terrestrial tribes in preserving a constant equilibrium between the relative numbers of different classes of animals and vegetables. If the insects become very numerous and devour the plants, these birds will immediately derive a larger portion of their subsistence from insects, just as the Arabians, Syrians, and Hottentots feed on locusts, when the locusts devour their crops.

Reciprocal influence of aquatic and terrestrial species.—The intimate relation of the inhabitants of the water to those of the land, and the influence exerted by each on the relative number of species, must not be overlooked amongst the complicated

causes which determine the existence of animals and plants in certain regions. A large proportion of the amphibious quadrupeds and reptiles prey partly on aquatic plants and animals, and in part on terrestrial; and a deficiency of one kind of prey causes them to have immediate recourse to the other. The voracity of certain insects, as the dragon-fly, for example, is confined to the water during one stage of their transformations, and in their perfect state to the air. Innumerable water-birds, both of rivers and seas, derive in like manner their food indifferently from either element; so that the abundance or scarcity of prey in one induces them either to forsake or more constantly to haunt the other. Thus an intimate connexion between the state of the animate creation in a lake or river, and in the adjoining dry land, is maintained; or between a continent, with its lakes and rivers, and the ocean. It is well known that many birds migrate, during stormy seasons, from the seashore into the interior, in search of food; while others, on the contrary, urged by like wants, forsake their inland haunts, and live on substances rejected by the tide.

The migration of fish into rivers during the spawning season supplies another link of the same kind. Suppose the salmon to be reduced in numbers by some marine foes, as by seals and grampuses, the consequence must often be, that in the course of a few years the otters at the distance of several hundred miles inland will be lessened in number from the scarcity of fish. On the other hand, if there be a dearth of food for the young fry of the salmon in rivers and estuaries, so that few return to the sea, the sand-eels and other marine species, which are usually kept down by the salmon, will swarm in greater profusion.

It is unnecessary to accumulate a greater number of illustrations in order to prove that the stations of different plants and animals depend on a great complication of circumstances,—on an immense variety of relations in the state of the animate and inanimate worlds. Every plant requires a certain climate, soil, and other conditions, and often the aid of many animals, in order to maintain its ground. Many animals feed on cer-

tain plants, being often restricted to a small number, and sometimes to one only ; other members of the animal kingdom feed on plant-eating species, and thus become dependent on the conditions of the *stations* not only of their prey, but of the plants consumed by them.

Having duly reflected on the nature and extent of these mutual relations in the different parts of the organic and inorganic worlds, we may next proceed to examine the results which may be anticipated from the fluctuations now continually in progress in the state of the earth's surface, and in the geographical distribution of its living productions.

CHAPTER IX.

The circumstances which constitute the *stations* of animals are changeable—Extension of the range of one species alters the condition of others—Supposed effects which may have followed the first entrance of the Polar bears into Iceland—The first appearance of a new species in a region causes the chief disturbance—Changes known to have resulted from the advance of human population—Whether man increases the productive powers of the earth—Indigenous quadrupeds and birds of Great Britain known to have been extirpated—Extinction of the Dodo—Rapid propagation of the domestic quadrupeds over the American continent—Power of exterminating species no prerogative of man—Concluding remarks.

THE CIRCUMSTANCES WHICH CONSTITUTE THE *STATIONS* OF ANIMALS ARE CHANGEABLE.

We have seen that the stations of animals and plants depend not merely on the influence of external agents in the inanimate world, and the relations of that influence to the structure and habits of each species, but also on the state of the contemporary living beings which inhabit the same part of the globe. In other words, the possibility of the existence of a certain species in a given locality, or of its thriving more or less therein, is determined not merely by temperature, humidity, soil, elevation, and other circumstances of the like kind, but also by the existence or non-existence, the abundance or scarcity, of a particular assemblage of other plants and animals in the same region.

If we show that both these classes of circumstances, whether relating to the animate or inanimate creation, are perpetually changing, it will follow that species are subject to incessant vicissitudes; and if the result of these mutations, in the course of ages, be so great as materially to affect the general condition of *stations*, it will follow that the successive destruction of species must now be part of the regular and constant order of Nature.

Extension of the range of one species alters the condition of others.—It will be desirable, first, to consider the effects which every extension of the numbers or geographical range of one species must produce on the condition of others inhabiting the same regions. When the necessary consequences of such extensions have been fully explained, the reader will be prepared to appreciate the important influence which slight modifications in the physical geography of the globe may exert on the condition of organic beings.

In the first place it is clear that, when any region is stocked with as great a variety of animals and plants as the productive powers of that region will enable it to support, the addition of any new species, or the *permanent* numerical increase of one previously established, must always be attended either by the local extermination or the numerical decrease of some other species.

There may undoubtedly be considerable fluctuations from year to year, and the equilibrium may be again restored without any permanent alteration; for, in particular seasons, a greater supply of heat, humidity, or other causes, may augment the total quantity of vegetable produce, in which case all the animals subsisting on vegetable food, and others which prey on them, may multiply without any one species giving way; but whenever the aggregate quantity of vegetable produce remains unaltered, the progressive increase of one animal or plant implies the decline of another.

All agriculturists and gardeners are familiar with the fact that, when weeds intrude themselves into the space appropriated to cultivated species, the latter are starved in their growth or stifled. If we abandon for a short time a field or garden, a host of indigenous plants,

The darnel, hemlock, and rank fumitory,

pour in and obtain the mastery, extirpating the exotics, or putting an end to the monopoly of some native plants.

If we inclose a park, and stock it with as many deer as the herbage will support, we cannot add sheep without lessening

the number of the deer; nor can other herbivorous species be subsequently introduced, unless the individuals of each species in the park become fewer in proportion.

So, if there be an island where leopards are the only beasts of prey, and the lion, tiger, and hyæna afterwards enter, the leopards, if they stand their ground, will be reduced in number. If the locusts then arrive and swarm greatly, it may deprive a large number of phytophagous animals of their food, and thereby cause a famine, not only among them, but among the beasts of prey;—certain species, perhaps, which had the weakest footing in the island will thus be annihilated.

We have seen how many distinct geographical provinces there are of aquatic and terrestrial species, and how great are the powers of migration conferred on different classes, whereby the inhabitants of one region may be enabled from time to time to invade another, and do actually so migrate and diffuse themselves over new countries. Now, although our knowledge of the history of the animate creation dates from so recent a period, that we can scarcely trace the advance or decline of any animal or plant, except in those cases where the influence of man has intervened, yet we can easily conceive what must happen when some new colony of wild animals or plants enters a region for the first time, and succeeds in establishing itself.

Supposed effects of the first entrance of the Polar bear into Iceland.—Let us consider how great are the devastations committed at certain periods by the Greenland bears, when they are drifted to the shores of Iceland in considerable numbers on the ice. These periodical invasions are formidable even to man; so that, when the bears arrive, the inhabitants collect together, and go in pursuit of them with fire-arms—each native who slays one being rewarded by the king of Denmark. The Danes of old, when they landed in their marauding expeditions upon our coast, hardly excited more alarm; nor did our islanders muster more promptly for the defence of their lives and property against a common

enemy than the modern Icelanders against these formidable brutes. It frequently happens, says Henderson, that the natives are pursued by the bear when he has been long at sea, and when his natural ferocity has been strengthened by the keenness of hunger; if unarmed, it is frequently by stratagem only that they make their escape *.

Let us cast our thoughts back to the period when the first Polar bears reached Iceland, before it was colonized by the Norwegians in 874; we may imagine the breaking up of an immense barrier of ice, like that which, in 1816 and the following year, disappeared from the east coast of Greenland, which it had surrounded for four centuries. By the aid of such means of transportation, a great number of these quadrupeds might effect a landing at the same time, and the havoc which they would make among the species previously settled in the island would be terrific. The deer, foxes, seals, and even birds, on which these animals sometimes prey, would be soon thinned down.

But this would be a part only, and probably an insignificant portion, of the aggregate amount of change brought about by the new invader. The plants on which the deer fed being less consumed in consequence of the lessened numbers of that herbivorous species, would soon supply more food to several insects, and probably to some terrestrial testacea, so that the latter would gain ground. The increase of these would furnish other insects and birds with food, so that the numbers of these last would be augmented. The diminution of the seals would afford a respite to some fish which they had persecuted; and these fish, in their turn, would then multiply and press upon their peculiar prey. Many water-fowls, the eggs and young of which are devoured by foxes, would increase when the foxes were thinned down by the bears; and the fish on which the water-fowls subsisted would then, in their turn, be less numerous. Thus the numerical proportions of a great number of the inhabitants, both of the land and sea, might be

* Journal of a Residence in Iceland, p. 276.

permanently altered by the settling of one new species in the region; and the changes caused indirectly might ramify through all classes of the living creation, and be almost endless.

An actual illustration of what we have here only proposed hypothetically, is in some degree afforded by the selection of small islands by the eider duck for its residence during the season of incubation; its nests being seldom if ever found on the shores of the main land, or even of a large island. The Icelanders are so well aware of this, that they have expended a great deal of labour in forming artificial islands, by separating from the main land certain promontories, joined to it by narrow isthmuses. This insular position is necessary to guard against the destruction of the eggs and young birds, by foxes, dogs, and other animals. One year, says Hooker *, it happened that, in the small island of Vidoc, adjoining the coast of Iceland, a fox got over *upon the ice*, and caused great alarm, as an immense number of ducks were then sitting on their eggs or young ones. It was long before he was taken, which was at last, however, effected by bringing another fox to the island, and fastening it by a string near the haunt of the former, by which he was allured within shot of the hunter.

The first appearance of a new species causes the chief disturbance.—It is usually the first appearance of an animal or plant, in a region to which it was previously a stranger, that gives rise to the chief alteration; since, after a time, an equilibrium is again established. But it must require ages before such a new adjustment of the relative forces of so many conflicting agents can be definitively settled. The causes in simultaneous action are so numerous, that they admit of an almost infinite number of combinations; and it is necessary that all these should have occurred once before the total amount of change, capable of flowing from any new disturbing force, can be estimated.

Thus, for example, suppose that once in two centuries a

* Tour in Iceland, vol. i., p. 64, second edition.

frost of unusual intensity, or a volcanic eruption of immense violence accompanied by floods from the melting of glaciers, should occur in Iceland; or an epidemic disease, fatal to the larger number of individuals of some one species, and not affecting others,—these, and a variety of other contingencies, all of which may occur at once, or at periods separated by different intervals of time, ought to happen before it would be possible for us to declare what ultimate alteration the presence of any new comer, such as the bear before-mentioned, might occasion in the animal population of the isle.

Every new condition in the state of the organic or inorganic creation, a new animal or plant, an additional snow-clad mountain, any permanent change, however slight in comparison to the whole, gives rise to a new order of things, and may make a material change in regard to some one or more species. Yet a swarm of locusts, or a frost of extreme intensity, may pass away without any great apparent derangement; no species may be lost, and all may soon recover their former relative numbers, because the same scourges may have visited the region again and again, at some former periods. Every plant that was incapable of resisting such a degree of cold, every animal which was exposed to be entirely cut off by famine, in consequence of the consumption of vegetation by the locusts, may have perished already, so that the subsequent recurrence of similar catastrophes is attended only by a temporary change.

CHANGES CAUSED BY MAN.

We are best acquainted with the mutations brought about by the progress of human population, and the growth of plants and animals favoured by man. To these, therefore, we should, in the first instance, turn our attention. If we conclude, from the concurrent testimony of history and of the evidence yielded by geological data, that man is, comparatively speaking, of very modern origin, we must at once perceive how great a revolution in the state of the animate world the increase of the

human race, considered merely as consumers of a certain quantity of organic matter, must necessarily cause.

Whether man increases the productive powers of the earth.— It may, perhaps, be said, that man has, in some degree, compensated for the appropriation to himself of so much food, by artificially improving the natural productiveness of soils, by irrigation, manure, and a judicious intermixture of mineral ingredients conveyed from different localities. But it admits of reasonable doubt, whether, upon the whole, we fertilize or impoverish the lands which we occupy. This assertion may seem startling to many, because they are so much in the habit of regarding the sterility or productiveness of land in relation to the wants of man, and not as regards the organic world generally. It is difficult, at first, to conceive, if a morass is converted into arable land, and made to yield a crop of grain, even of moderate abundance, that we have not improved the capabilities of the habitable surface—that we have not empowered it to support a larger quantity of organic life. In such cases, a tract, before of no utility to man, may be reclaimed and become of high agricultural importance, but it may yield, at the same time, a scantier vegetation. If a lake be drained and turned into a meadow, the space will provide sustenance to man, and many terrestrial animals serviceable to him, but not perhaps so much food as it previously yielded to the aquatic races.

If the pestiferous Pontine Marshes were drained and covered with corn, like the plains of the Po, they might, perhaps, feed a smaller number of animals than they do now; for these morasses are filled with herds of buffaloes and swine, and they swarm with birds, reptiles, and insects.

The felling of dense and lofty forests which covered, even within the records of history, a considerable space on the globe, now tenanted by civilized man, must usually have lessened the amount of vegetable food throughout the space where these woods grew. We must also take into our account

the area covered by towns, and a still larger surface occupied by roads.

If we force the soil to bear extraordinary crops one year, we are, perhaps, compelled to let it lie fallow the next. But nothing so much counterbalances the fertilizing effects of human art as the extensive cultivation of foreign herbs and shrubs, which, although they are often more nutritious to man, seldom thrive with the same rank luxuriance as the native plants of a district. Man is, in truth, continually striving to diminish the natural diversity of the *stations* of animals and plants in every country, and to reduce them all to a small number fitted for species of economical use. He may succeed perfectly in attaining his object, even though the vegetation be comparatively meagre, and the total amount of animal life be greatly lessened.

Spix and Martius have given a lively description of the incredible number of insects which lay waste the crops in Brazil, besides swarms of monkeys, flocks of parrots, and other birds, as well as the paca, agouti, and wild swine. They describe the torment which the planter and the naturalist suffer from the musquitoes, and the devastation of the ants and blattæ; they speak of the dangers to which they were exposed from the jaguar, the poisonous serpents, lizards, scorpions, centipedes, and spiders. But with the increasing population and cultivation of the country, observe these naturalists, these evils will gradually diminish; when the inhabitants have cut down the woods, drained the marshes, made roads in all directions, and founded villages and towns, man will by degrees triumph over the rank vegetation and the noxious animals, and all the elements will second and amply recompense his activity *.

The number of human beings now peopling the earth is supposed to amount to eight hundred millions, so that we may easily understand how great a number of beasts of prey, birds,

* Travels in Brazil, vol. i., p. 260.

and animals of every class, this prodigious population must have displaced, independently of the still more important consequences which have followed from the derangement brought about by man in the relative numerical strength of particular species.

Indigenous quadrupeds and birds extirpated in Great Britain.—Let us make some inquiries into the extent of the influence which the progress of society has exerted during the last seven or eight centuries, in altering the distribution of our indigenous British animals. Dr. Fleming has prosecuted this inquiry with his usual zeal and ability, and in a memoir * on the subject has enumerated the best-authenticated examples of the decrease or extirpation of certain species during a period when our population has made the most rapid advances. We shall offer a brief outline of his results.

The stag, as well as the fallow deer and the roe, were formerly so abundant that, according to Lesley, from five hundred to a thousand were sometimes slain at a hunting-match; but the native races would already have been extinguished, had they not been carefully preserved in certain forests. The otter, the marten, and the polecat, were also in sufficient numbers to be pursued for the sake of their fur; but they have now been reduced within very narrow bounds. The wild cat and fox have also been sacrificed throughout the greater part of the country, for the security of the poultry-yard or the fold. Badgers have been expelled from nearly every district which at former periods they inhabited.

Besides these, which have been driven out from some haunts, and everywhere reduced in number, there are some which have been wholly extirpated; such as the ancient breed of indigenous horses, the wild boar, and the wild oxen, of which last, however, a few remains are still preserved in the parks of some of our nobility. The beaver, which was eagerly sought after for its fur, had become scarce at the close of the ninth century, and, by the twelfth century, was only to be met with, accord-

* Ed. Phil. Journ., No. xxii., p. 287. Oct. 1824.

ing to Giraldus de Barri, in one river in Wales, and another in Scotland. The wolf, once so much dreaded by our ancestors, is said to have maintained its ground in Ireland so late as the beginning of the eighteenth century (1710), though it had been extirpated in Scotland thirty years before, and in England at a much earlier period. The bear, which in Wales was regarded as a beast of the chace equal to the hare or the boar *, only perished as a native of Scotland in the year 1057 †.

Many native birds of prey have also been the subjects of unremitting persecution. The eagles, larger hawks, and ravens, have disappeared from the more cultivated districts. The haunts of the mallard, the snipe, the redshank, and the bittern, have been drained equally with the summer dwellings of the lapwing and the curlew. But these species still linger in some portion of the British isles; whereas the large capercailzies, or wood grouse, formerly natives of the pine-forests of Ireland and Scotland, have been destroyed within the last fifty years. The egret and the crane, which appear to have been formerly very common in Scotland, are now only occasional visitants ‡.

The bustard (*Otis tarda*), observes Graves in his British Ornithology §, 'was formerly seen in the downs and heaths of various parts of our island, in flocks of forty or fifty birds; whereas it is now a circumstance of rare occurrence to meet with a single individual.' Bewick also remarks, 'that they were formerly more common in this island than at present; they are now found only in the open counties of the south and east, in the plains of Wiltshire, Dorsetshire, and some parts of Yorkshire.' In the few years that have elapsed since Bewick wrote, this bird has entirely disappeared from Wiltshire and Dorsetshire ||.

These changes, we may observe, are derived from very im-

* Ray, Syn. Quad., p. 214. † Fleming, Ed. Phil. Journ., No. xxii. p. 295.
‡ Fleming, ibid., p. 292. § Vol. iii., London, 1821.
|| Land Birds, vol. i. p. 316, Ed. 1821.

perfect memorials, and relate only to the larger and more conspicuous animals inhabiting a small spot on the globe; but they cannot fail to exalt our conception of the enormous revolutions which, in the course of several thousand years, the whole human species must have effected.

Extinction of the Dodo.—The kangaroo and the emu are retreating rapidly before the progress of colonization in Australia; and it scarcely admits of doubt, that the general cultivation of that country must lead to the extirpation of both. The most striking example of the loss, even within the last two centuries, of a remarkable species, is that of the dodo—a bird first seen by the Dutch when they landed on the Isle of France, at that time uninhabited, immediately after the discovery of the passage to the East Indies by the Cape of Good Hope. It was of a large size and singular form; its wings short, like those of an ostrich, and wholly incapable of sustaining its heavy body, even for a short flight. In its general appearance it differed from the ostrich, cassowary, or any known bird.

Many naturalists gave figures of the dodo after the commencement of the seventeenth century, and there is a painting of it in the British Museum, which is said to have been taken from a living individual. Beneath the painting is a leg, in a fine state of preservation, which ornithologists are agreed cannot belong to any other known bird. In the museum at Oxford, also, there is a foot and a head, in an imperfect state, but M. Cuvier doubts the identity of this species with that of which the painting is preserved in London *.

* Some have complained that inscriptions on tomb-stones convey no general information except that individuals were born and died, accidents which must happen alike to all men. But the death of a *species* is so remarkable an event in natural history, that it deserves commemoration, and it is with no small interest that we learn, from the archives of the University of Oxford, the exact day and year when the remains of the last specimen of the dodo, which had been permitted to rot in the Ashmolean museum, were cast away. The relics, we are told, were 'a Musæo subducta, annuente Vice-cancellario aliisque curatoribus, ad ea lustranda convocatis, die Januarii, 8vo., A.D., 1755.'—Zool. Journ., No. 12, p. 559. 1828.

In spite of the most active search, during the last century, no information respecting the dodo was obtained, and some authors have gone so far as to pretend that it never existed; but amongst a great mass of satisfactory evidence in favour of the recent existence of this species, we may mention that an assemblage of fossil bones were recently discovered, under a bed of lava, in the Isle of France, and sent to the Paris museum by M. Desjardins. They almost all belonged to a large living species of land-tortoise, called *Testudo Indica*, but amongst them were the head, sternum, and humerus of the dodo. M. Cuvier showed me these valuable remains in Paris, and assured me that they left no doubt in his mind that the huge bird was one of the gallinaceous tribe *.

Rapid propagation of domestic quadrupeds over the American continent.—Next to the direct agency of man, his indirect influence in multiplying the numbers of large herbivorous quadrupeds of domesticated races, may be regarded as one of the most obvious causes of the extermination of species. On this, and on several other grounds, the introduction of the horse, ox, and other mammalia, into America, and their rapid propagation over that continent within the last three centuries, is a fact of great importance in natural history. The extraordinary herds of wild cattle and horses which overran the plains of South America, sprung from a very few pairs first carried over by the Spaniards; and they prove that the wide geographical range of large species in great continents does not necessarily imply that they have existed there from remote periods.

Humboldt observes, in his Travels †, on the authority of Azzara, that it is believed there exist, in the Pampas of Buenos Ayres, twelve million cows and three million horses, without comprising in this enumeration the cattle that have no acknowledged proprietor. In the Llanos of Caraccas, the rich hateros, or proprietors of pastoral farms, are entirely ignorant of the

* Sur quelques Ossemens, &c.—Ann. des Sci., tome xxi. p. 103. Sept. 1830.

† Pers. Nar. vol. iv.

number of cattle they possess. The young are branded with a mark peculiar to each herd, and some of the most wealthy owners mark as many as fourteen thousand a year. In the northern plains, from the Orinoco to the lake of Maracaybo, M. Depons reckoned that one million two hundred thousand oxen, one hundred and eighty thousand horses, and ninety thousand mules, wandered at large *. In some parts of the valley of the Mississippi, especially in the country of the Osage Indians, wild horses are immensely numerous.

The establishment of black cattle in America dates from Columbus's second voyage to St. Domingo. They there multiplied rapidly; and that island presently became a kind of nursery from which these animals were successively transported to various parts of the continental coast, and from thence into the interior. Notwithstanding these numerous exportations, in twenty-seven years after the discovery of the island, herds of four thousand head, as we learn from Oviedo, were not uncommon, and there were even some that amounted to eight thousand. In 1587, the number of hides exported from St. Domingo alone, according to Acosta's report, was thirty-five thousand four hundred and forty-four; and in the same year there were exported sixty-four thousand three hundred and fifty from the ports of New Spain. This was in the sixty-fifth year after the taking of Mexico, previous to which event the Spaniards, who came into that country, had not been able to engage in anything else than war †.

All our readers are aware that these animals are now established throughout the American continent, from Canada to Paraguay.

The ass has thriven very generally in the New World; and we learn from Ulloa, that in Quito they ran wild, and multiplied in amazing numbers, so as to become a nuisance. They grazed together in herds, and when attacked, defended themselves with their mouths. If a horse happened to stray into

* Quarterly Review, vol. xxi. p. 335. † Ibid.

the places where they fed, they all fell upon him, and did not cease biting and kicking till they left him dead *.

The first hogs were carried to America by Columbus, and established in the island of St. Domingo the year following its discovery in November, 1493. In succeeding years they were introduced into other places where the Spaniards settled; and, in the space of half a century, they were found established in the New World, from the latitude of 25° north, to the 40th degree of south latitude. Sheep, also, and goats have multiplied enormously in the New World, as have also the cat and the rat, which last, as we before stated, has been imported unintentionally in ships. The dogs introduced by man, which have at different periods become wild in America, hunted in packs, like the wolf and the jackal, destroying not only hogs, but the calves and foals of the wild cattle and horses.

Ulloa in his voyage, and Buffon on the authority of old writers, relate a fact which illustrates very clearly the principle before explained by us, of the check which the increase of one animal necessarily offers to that of another. The Spaniards had introduced goats into the island of Juan Fernandez, where they became so prolific as to furnish the pirates who infested those seas with provisions. In order to cut off this resource from the buccaneers, a number of dogs were turned loose into the island; and so numerous did they become in their turn, that they destroyed the goats in every accessible part, after which the number of the wild dogs again decreased †.

Increase of rein-deer imported into Iceland.—As an example of the rapidity with which a large tract may become peopled by the offspring of a single pair of quadrupeds, we may mention, that in the year 1773 thirteen rein-deer were exported from Norway, only three of which reached Iceland. These were turned loose into the mountains of Guldbringè Syssel, where they multiplied so greatly, in the course of forty

* Ulloa's Voyage. Wood's Zoog., vol. i. p. 9.

† Buffon, vol. v. p. 100. Ulloa's Voyage, vol. ii. p. 220.

years, that it was not uncommon to meet with herds consisting of from forty to one hundred in various districts.

In Lapland, observes a modern writer, the rein-deer is a loser by his connexion with man, but Iceland will be this creature's paradise. There is, in the interior, a tract which Sir G. Mackenzie computes at not less than forty thousand square miles, without a single human habitation, and almost entirely unknown to the natives themselves. There are no wolves; the Icelanders will keep out the bears; and the rein-deer, being almost unmolested by man, will have no enemy whatever, unless it has brought with it its own tormenting gad-fly *.

Besides the quadrupeds before enumerated by us, our domestic fowls have also succeeded in the West Indies and America, where they have the common fowl, the goose, the duck, the peacock, the pigeon, and the guinea-fowl. As these were often taken suddenly from the temperate to very hot regions, they were not reared at first without much difficulty; but after a few generations they became familiarized to the climate, which, in many cases, approached much nearer than that of Europe to the temperature of their original native countries.

The fact of so many millions of wild and tame individuals of our domestic species, almost all of them the largest quadrupeds and birds, having been propagated throughout the new continent within the short period that has elapsed since the discovery of America, while no appreciable improvement can have been made in the productive powers of that vast continent, affords abundant evidence of the extraordinary changes which accompany the diffusion and progressive advancement of the human race over the globe. That it should have remained for us to witness such mighty revolutions is a proof, even if there was no other evidence, that the entrance of man into the planet is, comparatively speaking, of extremely modern date, and that the effects of his agency are only beginning to be felt.

Population which the globe is capable of supporting.—A

* Travels in Iceland in 1810, p. 342.

modern writer has estimated, that there are in America upwards of four million square miles of useful soil, each capable of supporting two hundred persons; and nearly six million, each mile capable of supporting four hundred and ninety persons *. If this conjecture be true, it will follow, as that author observes, that if the natural resources of America were fully developed, it would afford sustenance to five times as great a number of inhabitants as the entire mass of human beings existing at present upon the globe. The new continent, he thinks, though less than half the size of the old, contains an equal quantity of useful soil, and much more than an equal amount of productive power. Be this as it may, we may safely conclude that the amount of human population now existing, constitutes but a small proportion of that which the globe is capable of supporting, or which it is destined to sustain at no distant period, by the rapid progress of society, especially in America, Australia, and certain parts of the old continent.

Power of exterminating species no prerogative of man.—But if we reflect that already many millions of square miles of the most fertile land, occupied originally by a boundless variety of animal and vegetable forms, have been already brought under the dominion of man, and compelled, in a great measure, to yield nourishment to him, and to a limited number of plants and animals which he has caused to increase, we must at once be convinced, that the annihilation of a multitude of species has already been effected, and will continue to go on hereafter, in certain regions, in a still more rapid ratio, as the colonies of highly-civilized nations spread themselves over unoccupied lands.

Yet, if we wield the sword of extermination as we advance, we have no reason to repine at the havoc committed, nor to fancy with the Scotch poet, that 'we violate the social union of nature;' or complain with the melancholy Jaques, that we

> Are mere usurpers, tyrants, and what's worse,
> To fright the animals and to kill them up
> In their assign'd and native dwelling-place.

* Maclaren, Art. America. Encyc. Britannica.

We have only to reflect, that in thus obtaining possession of the earth by conquest, and defending our acquisitions by force, we exercise no exclusive prerogative. Every species which has spread itself from a small point over a wide area must, in like manner, have marked its progress by the diminution or the entire extirpation of some other, and must maintain its ground by a successful struggle against the encroachments of other plants and animals. That minute parasitic plant, called 'the rust' in wheat, has, like the Hessian fly, the locust, and the aphis, caused famines ere now amongst the 'lords of the creation.' The most insignificant and diminutive species, whether in the animal or vegetable kingdom, have each slaughtered their thousands, as they disseminated themselves over the globe, as well as the lion, when first it spread itself over the tropical regions of Africa.

Concluding remarks.—We cannot conclude this division of our subject without observing, that although we have as yet considered one class only of the causes (the organic) whereby species may become exterminated, yet the continued action of these alone, throughout myriads of future ages, must work an entire change in the state of the organic creation, not merely on the continents and islands, where the power of man is chiefly exerted, but in the great ocean, where his control is almost unknown. The mind is prepared by the contemplation of such future revolutions to look for the signs of others, of an analogous nature, in the monuments of the past. Instead of being astonished at the proofs there manifested of endless mutations in the animate world, they will appear to one, who has thought profoundly on the fluctuations now in progress, to afford evidence in favour of the uniformity of the system, unless, indeed, we are precluded from speaking of *uniformity* when we characterize a principle of endless variation.

CHAPTER X.

Influence of inorganic causes in changing the habitations of species—Powers of diffusion indispensable, that each species may maintain its ground—How changes in the physical geography affect the distribution of species—Rate of the change of species cannot be uniform, however regular the action of the inorganic causes—Illustration derived from subsidences by earthquakes—from the elevation of land by the same—from the formation of new islands—from the wearing through of an isthmus—Each change in the physical geography of large regions must occasion the extinction of species—Effects of a general alteration of climate on the migration of species—Gradual refrigeration causes species in the northern and southern hemispheres to become distinct—elevation of temperature the reverse—Effects in the distribution of species which must result from vicissitudes in climate inconsistent with the theory of transmutation.

INFLUENCE OF INORGANIC CAUSES IN CHANGING THE HABITATIONS OF SPECIES.

Having shown in the last chapter how considerably the numerical increase or the extension of the geographical range of any one species must derange the numbers and distribution of others, let us now direct our attention to the influence which the inorganic causes described in our first volume are continually exerting on the habitations of species.

So great is the instability of the earth's surface, that if Nature were not continually engaged in the task of sowing seeds and colonizing animals, the depopulation of a certain portion of the habitable sea and land would in a few years be considerable. Whenever a river transports sediment into a lake or sea, the aquatic animals and plants which delight in deep water are expelled: the tract, however, is not allowed to remain useless, but is soon peopled by species which require more light and heat, and thrive where the water is shallow. Every addition made to the land by the encroachment of the delta of a river banishes many subaqueous species from their native abodes; but the new-formed plain is not permitted to

lie unoccupied, being instantly covered with terrestrial vegetation. The ocean devours continuous lines of sea-coast, and precipitates forests or rich pasture land into the waves; but this space is not lost to the animate creation, for shells and sea-weed soon adhere to the new-made cliffs, and numerous fish people the channel which the current has scooped out for itself. No sooner has a volcanic isle been thrown up than some lichens begin to grow upon it, and it is sometimes clothed with verdure, while smoke and ashes are still occasionally thrown from the crater. The cocoa, pandanus, and mangrove take root upon the coral reef before it has fairly risen above the waves. The burning stream of lava that descends from Etna rolls through the stately forest, and converts to ashes every tree and herb which stands in its way; but the black strip of land thus desolated is covered again, in the course of time, with oaks, pines, and chesnuts, as luxuriant as those which the fiery torrent swept away.

Every flood and landslip, every wave which a hurricane or earthquake throws upon the shore, every shower of volcanic dust and ashes which buries a country far and wide to the depth of many feet, every advance of the sand-flood, every conversion of salt-water into fresh when rivers alter their main channel of discharge, every permanent variation in the rise or fall of tides in an estuary—these and countless other causes displace in the course of a few centuries certain plants and animals from stations which they previously occupied. If, therefore, the Author of Nature had not been prodigal of those numerous contrivances, before alluded to, for spreading all classes of organic beings over the earth—if he had not ordained that the fluctuations of the animate and inanimate creation should be in perfect harmony with each other, it is evident that considerable spaces, now the most habitable on the globe, would soon be as devoid of life as are the Alpine snows, or the dark abysses of the ocean, or the moving sands of the Sahara.

Powers of diffusion indispensable that each species may

maintain its ground.—The powers then of migration and diffusion conferred on animals and plants are indispensable to enable them to maintain their ground, and would be necessary even though it were never intended that a species should gradually extend its geographical range. But a facility of shifting their quarters being once given, it cannot fail to happen that the inhabitants of one province should occasionally penetrate into some other, since the strongest of those barriers which we before described as separating distinct regions are all liable to be thrown down, one after the other, during the vicissitudes of the earth's surface.

How changes in physical geography affect the distribution of species.—The numbers and distribution of particular species are affected in two ways, by changes in the physical geography of the earth. First, these changes promote or retard the migrations of species; secondly, they alter the physical conditions of the localities which species inhabit. If the ocean should gradually wear its way through an isthmus, like that of Suez, it would open a passage for the intermixture of the aquatic tribes of two seas previously disjoined, and would, at the same time, close a free communication which the terrestrial plants and animals of two continents had before enjoyed. These would be, perhaps, the most important consequences in regard to the distribution of species, which would result from the breach made by the sea in such a spot; but there would be others of a distinct nature, such as the conversion of a certain tract of land which formed the isthmus into sea. This space previously occupied by terrestrial plants and animals would be immediately delivered over to the aquatic, a local revolution which might have happened in innumerable other parts of the globe, without being attended by any alteration in the blending together of species of two distinct provinces.

Rate of change of species cannot be uniform.—This observation leads us to point out one of the most interesting conclusions to which we are led by the contemplation of the vicissitudes of the inanimate world in relation to those of the animate.

It is clear that, if the agency of inorganic causes be uniform, as we have supposed, they must operate very irregularly on the state of organic beings, so that the rate according to which these will change in particular regions, will not be equal in equal periods of time.

We are not about to advocate the doctrine of general catastrophes recurring at certain intervals, as in the ancient oriental cosmogonies, nor do we doubt that, if very considerable periods of equal duration could be taken into our consideration and compared one with another, the rate of change in the living, as well as in the inorganic world, would be nearly uniform; but if we regard each of the causes separately, which we know to be at present the most instrumental in remodelling the state of the surface, we shall find that we must expect each to be in action for thousands of years, without producing any extensive alterations in the habitable surface, and then to give rise, during a very brief period, to important revolutions.

We shall illustrate this principle by a few of the most remarkable examples which present themselves. In the course of the last century, as we have before pointed out, a considerable number of instances are recorded of the solid surface, whether covered by water or not, having been permanently sunk or upraised by the power of earthquakes. Most of these convulsions are only accompanied by temporary fluctuations in the state of limited districts, and a continued repetition of these events for thousands of years might not produce any decisive change in the state of many of those great zoological or botanical provinces of which we have sketched the boundaries.

Illustration derived from subsidences by earthquakes.—When, for example, large parts of the ocean and even of inland seas are a thousand fathoms or upwards in depth, it is a matter of no moment to the animate creation that vast tracts should be heaved up many fathoms at certain intervals, or should subside to the same amount. Neither can any material revolution be produced in South America either in the terrestrial or the

marine plants or animals by a series of shocks on the coast of Chili, each of which, like that of Penco, in 1750, should uplift the coast about twenty-five feet. Nor if the ground sinks fifty feet at a time, as in the harbour of Port Royal, in Jamaica, in 1692, will such alterations of level work any general fluctuations in the state of organic beings inhabiting the West India islands, or the Caribbean Sea.

It is only when these subterranean powers, by shifting gradually the points where their principal force is developed, happen to strike upon some particular region where a slight change of level immediately affects the distribution of land and water, or the state of the climate, or the barriers between distinct groups of species over extensive areas, that the rate of fluctuation becomes accelerated, and may, in the course of a few years or centuries, work mightier changes than had been experienced in myriads of antecedent years.

Thus, for example, a repetition of subsidences causing the narrow isthmus of Panamá to sink down a few hundred feet, might in a few centuries bring about a great revolution in the state of the animate creation in the western hemisphere. Thousands of aquatic species would pass for the first time from the Caribbean Sea into the Pacific; and thousands of others, before peculiar to the Pacific Ocean, would make their way into the Caribbean Sea, the Gulf of Mexico, and the Atlantic. A considerable modification would probably be occasioned by the same event in the direction or volume of the Gulf stream, and thereby the temperature of the sea and the contiguous lands would be altered as far as the influence of that current extends. A change of climate might thus be produced in the ocean from Florida to Spitzbergen, and in many countries of North America, Europe, and Greenland. Not merely the heat, but the quantity of rain which falls would be altered in certain districts, so that many species would be excluded from tracts where they before flourished; others would be reduced in number; and some would thrive more and multiply. The seeds also and the fruits of plants would no longer be drifted

in precisely the same directions, nor the eggs of aquatic animals; neither would species be any longer impeded in their migrations towards particular stations before shut out from them by their inability to cross the mighty current.

Let us take another example from a part of the globe which is at present liable to suffer by earthquakes, namely, the low sandy tract which intervenes between the sea of Azof and the Caspian. If there should occur a sinking down to a trifling amount, and such ravines should be formed as might be produced by a few earthquakes, not more considerable than have fallen within our limited observation during the last one hundred and forty years, the waters of the sea of Azof would pour rapidly into the Caspian, which, according to the late observations of Humboldt *, is 300 feet below the level of the Black Sea. The Sea of Azof would immediately borrow from the Euxine, the Euxine from the Mediterranean, and the Mediterranean from the Atlantic, so that an inexhaustible current would pour down into the low tracts of Asia bordering the Caspian, by which all the sandy salt steppes adjacent to that sea would be inundated. An area of at least 18,000 square leagues, now below the level of the Mediterranean, would be converted from land into sea.

The diluvial waters would reach the salt lake of Aral, nor stop until their eastern shores were bounded by the high land which in the steppe of the Kirghis connects the Altay with the Himalaya mountains. Saratof, Orenburg, and the low regions of the Oxus and Jaxartes, would be submerged. A few years, perhaps a few months, might suffice for the accomplishment of this great revolution in the geography of the interior of Asia; and it is impossible for those who believe in the permanence of the energy with which existing causes now act, not to anticipate analogous events again and again in the course of future ages.

Illustration derived from the elevation of land —Let us next imagine a few cases of the elevation of land of small extent at certain critical points, as, for example, in the shallowest parts

* Fragmens de Géologie, &c., 1831.

of the Straits of Gibraltar, where the soundings from the African to the European side give only two hundred and twenty fathoms. In proportion as this submarine barrier of rock was upheaved, to effect which would merely require the shocks of partial and confined earthquakes, the volume of water which pours in from the Atlantic into the Mediterranean would be lessened. But the loss of the inland sea by evaporation would remain the same, so that being no longer able to draw on the ocean for a supply sufficient to restore its equilibrium, it must sink, and leave dry a certain portion of land around its borders. The current which now flows constantly out of the Black Sea into the Mediterranean would then rush in more rapidly, and the level of the Mediterranean would be thereby prevented from falling so low; but the level of the Black Sea would, for the same reason, sink, so that when, by a continued series of elevatory movements, the Straits of Gibraltar had become completely closed up, we might expect large and level sandy steppes to surround both the Euxine and Mediterranean, like those occurring at present on the skirts of the Caspian, and the Lake of Aral. The geographical range of hundreds of aquatic species would be thereby circumscribed, and that of hundreds of terrestrial plants and animals extended.

A line of submarine volcanos crossing the channel of some strait, and gradually choking it up with ashes and lava, might produce a new barrier as effectually as a series of earthquakes; especially if thermal springs, plentifully charged with carbonate of lime, silica, and other mineral ingredients, should promote the rapid multiplication of corals and shells, and cement them together with solid matter precipitated during the intervals between eruptions. Suppose in this manner a stoppage to be caused of the Bahama Channel between the bank of that name and the coast of Florida. This insignificant revolution, confined to a mere spot in the bottom of the ocean, would, by diverting the main current of the Gulf stream, give rise more effectually than the opening of the Straits of Panamá before supposed, to extensive changes in the climate and

distribution of animals and plants inhabiting the northern hemisphere.

Illustration from the formation of new islands.—A repetition of elevatory movements of earthquakes might continue over an area as extensive as Europe, for thousands of ages, at the bottom of the ocean in certain regions, and produce no visible effects; whereas, if they should operate in some shallow parts of the Pacific, amid the coral archipelagos, they would soon give birth to a new continent. Hundreds of volcanic islands may be thrown up and become covered with vegetation, without causing more than local fluctuations in the animate world; but if a chain like the Aleutian archipelago or the Kurile isles run for a distance of many hundred miles, so as to form an almost uninterrupted communication between two continents, or two distant islands, the migrations of plants, birds, insects, and even of some quadrupeds, may cause in a short time an extraordinary series of revolutions, tending to augment the range of some animals and plants, and to limit that of others. A new archipelago might be formed in the Mediterranean, the Bay of Biscay, and a thousand other localities, and might produce less important events than one rock which should rise up between Australia and Java, so placed that winds and currents might cause an interchange of the plants, insects, and birds, of the latter country.

From the wearing through of an isthmus.—If we turn from the igneous to the aqueous agents, we find the same tendency to an irregular rate of change, naturally connected with the strictest uniformity in the energy of those causes. When the sea, for example, gradually encroaches upon both sides of a narrow isthmus, as that of Sleswick, separating the North Sea from the Baltic, where, as we stated, the cliffs on both the opposite coasts are wasting away *, no material alteration results for thousands of years, save only that there is a progressive conversion of a small strip of land into water. A few feet

* Vol i. chap. xvi.

only, or a few yards, are annually removed; but when at last the partition shall be broken down, and the tides of the ocean shall enter by a direct passage into the inland sea, instead of going by a circuitous route through the Cattegat, a body of salt-water will sweep up as far as the Gulfs of Bothnia and Finland, the waters of which are now brackish, or almost fresh; and this revolution will be attended by the local annihilation of many species.

Similar consequences must have resulted, on a small scale, when the sea opened its way through the isthmus of Staveren in the thirteenth century, forming an union between an inland lake and the ocean, and opening, in the course of one century, a shallow strait more than half as wide as the narrowest part of that which divides England from France.

Changes in physical geography which must occasion extinction of species.—It will almost seem superfluous, after we have thus traced the important modifications in the condition of living beings which flow from changes of trifling extent, to argue that entire revolutions might be brought about, if the climate and physical geography of the whole globe were greatly altered. Species, we have stated, are in general local, some being confined to extremely small spots, and depending for their existence on a combination of causes, which, if they are to be met with elsewhere, occur only in some very remote region. Hence it must happen that, when the nature of these localities is changed, the species will perish; for it will rarely happen that the cause which alters the character of the district will afford new facilities to the species to establish itself elsewhere.

African desert.—If we attribute the origin of a great part of the desert of Africa to the gradual progress of moving sands, driven eastward by the westerly winds, we may safely infer that a variety of species must have been annihilated by this cause alone. The sand-flood has been inundating, from time immemorial, the rich lands on the west of the Nile, and we

have only to multiply this effect a sufficient number of times, in order to understand how, in the lapse of ages, a whole group of terrestrial animals and plants may become extinct.

This desert, without including Bornou and Darfour, extends, according to the calculation of Humboldt, over 194,000 square leagues, an area far more than double that of the Mediterranean, which occupies only 79,800 square leagues. In a small portion of so vast a space, we may infer from analogy that there were many peculiar species of plants and animals which must have been banished by the sand, and their habitations invaded by the camel and by birds and insects formed for the arid sands.

There is evidently nothing in the nature of the catastrophe to favour the escape of the former inhabitants to some adjoining province; nothing to weaken, in the bordering lands, that powerful barrier against emigration—pre-occupancy. Nor, even if the exclusion of a certain group of species from a given tract were compensated by an extension of their range over a new country, would that circumstance tend to the conservation of species in general; for the extirpation would merely then be transferred to the region so invaded. If it be imagined, for example, that the aboriginal quadrupeds, birds, and other animals of Africa emigrated in consequence of the advance of drift-sand, and colonized Arabia, the indigenous Arabian species must have given way before them, and have been reduced in number or destroyed.

Let us next suppose that, in some central and more elevated parts of the great African desert, the upheaving power of earthquakes should be exerted throughout an immense series of ages, accompanied at certain intervals by volcanic eruptions, such as gave rise at once, in 1755, to a mountain 1600 feet high, on the Mexican plateau. When the continued repetition of these events had caused a mountain-chain, it is obvious that a complete transformation in the state of the climate would be brought about throughout a vast area.

We will imagine the summits of the new chain to rise so as

to be covered, like Mount Atlas, for several thousand feet, with snow, during a great part of the year. The melting of these snows, during the greatest heat, would cause the rivers to swell in the season when the greatest drought now prevails; the waters, moreover, derived from this source, would always be of lower temperature than the surrounding atmosphere, and would thus contribute to cool the climate. During the numerous earthquakes and volcanic eruptions which would attend the gradual formation of the chain, there would be many floods caused by the bursting of temporary lakes and by the melting of snows by lava. These inundations would deposit alluvial matter far and wide over the original sands at all levels, as the country assumed various shapes, and was modified again and again by the moving power from below, and the aqueous erosion of the surface above. At length the Sahara would be fertilized, irrigated by rivers and streamlets intersecting it in every direction, and covered by jungle and morasses, so that the animals and plants which now people Northern Africa would disappear, and the region would gradually become fitted for the reception of a population of species perfectly dissimilar in their forms, habits, and organization.

There are always some peculiar and characteristic features in the physical geography of each large division of the globe; and on these peculiarities the state of animal and vegetable life is dependent. If, therefore, we admit incessant fluctuations in the physical geography, we must, at the same time, concede the successive extinction of terrestrial and aquatic species to be part of the economy of our system. When some great class of stations is in excess in certain latitudes, as, for example, in wide savannahs, arid sands, lofty mountains, or inland seas, we find a corresponding development of species adapted for such circumstances. In North America, where there is a chain of vast inland lakes of fresh water, we find an extraordinary abundance and variety of aquatic birds, fresh water fish, testacea, and small amphibious reptiles, fitted for such a climate. The greater part of these would perish if the lakes were de-

stroyed,—an event that might be brought about by some of the least of those important revolutions contemplated in geology. It might happen that no fresh water lakes of corresponding magnitude might then exist on the globe; but if they occurred elsewhere, they might be situated in New Holland, Southern Africa, Eastern Asia, or some region so distant as to be quite inaccessible to the North American species; or they might be situated within the tropics, in a climate uninhabitable by species fitted for a temperate zone; or, finally, we may presume that they would be preoccupied by *indigenous* tribes.

To pursue this train of reasoning farther is unnecessary; the reader has only to reflect on what we have said of the habitations and the stations of organic beings in general, and to consider them in relation to those effects which we have contemplated in our first volume as resulting from the igneous and aqueous causes now in action, and he will immediately perceive that, amidst the vicissitudes of the earth's surface, species cannot be immortal, but must perish one after the other, like the individuals which compose them. There is no possibility of escaping from this conclusion, without resorting to some hypothesis as violent as that of Lamarck, who imagined, as we have before seen, that species are each of them endowed with indefinite powers of modifying their organization, in conformity to the endless changes of circumstances to which they are exposed.

EFFECTS OF A GENERAL ALTERATION IN CLIMATE ON THE DISTRIBUTION OF SPECIES.

Some of the effects which must attend every general alteration of *climate* are sufficiently peculiar to claim a separate consideration before concluding the present chapter.

We have before stated that, during seasons of extraordinary severity, many northern birds, and, in some countries, many quadrupeds, migrate southwards. If these cold seasons were to become frequent, in consequence of a gradual and general

refrigeration of the atmosphere, such migrations would be more and more regular, until, at length, many animals, now confined to the arctic regions, would become the tenants of the temperate zone; while the inhabitants of the latter would approach nearer to the equator. At the same time, many species previously established on high mountains would begin to descend, in every latitude, towards the middle regions, and those which were confined to the flanks of mountains would make their way into the plains. Analogous changes would also take place in the vegetable kingdom.

If, on the contrary, the heat of the atmosphere be on the increase, the plants and animals of low grounds would ascend to higher levels, the equatorial species would migrate into the temperate zone, and those of the temperate into the arctic circle.

But although some species might thus be preserved, every great change of climate must be fatal to many which can find no place of retreat, when their original habitations become unfit for them. For if the general temperature be on the rise, then is there no cooler region whither the polar species can take refuge; if it be on the decline, then the animals and plants previously established between the tropics have no resource. Suppose the general heat of the atmosphere to increase, so that even the arctic region became too warm for the musk-ox and rein-deer, it is clear that they must perish; so, if the torrid zone should lose so much of its heat by the progressive refrigeration of the earth's surface, as to be an unfit habitation for apes, boas, bamboos, and palms, these tribes of animals and plants, or at least most of the species now belonging to them, would become extinct, for there would be no warmer latitudes for their reception.

It will follow, therefore, that as often as the climates of the globe are passing from the extreme of heat to that of cold—from the summer to the winter of the great year before alluded to by us *—the migratory movement will be directed con-

* Vol. i. chap. vii.

stantly from the poles towards the equator; and for this reason the species inhabiting parallel latitudes, in the northern and southern hemispheres, must become widely different. For we assume, on grounds before stated *, that the original stock of each species is introduced into one spot of the earth only, and, consequently, no species can be at once indigenous in the arctic and antarctic circles.

But when, on the contrary, a series of changes in the physical geography of the globe, or any other supposed cause, occasions an elevation of the general temperature,—when there is a passage from the winter to one of the vernal or summer seasons of the great cycle of climates, then the order of the migratory movement is inverted. The different species of animals and plants direct their course from the equator towards the poles; and the northern and southern hemispheres may become peopled, to a great degree, by identical species. Such is not the actual state of the inhabited earth, as we have already shown in our sketch of the geographical distribution of its living productions; and this fact adds one more additional proof to a great body of evidence, derived from independent sources, that the general temperature has been cooling down during the epochs which immediately preceded our own.

We do not mean to speculate on the entire transposition of a group of animals and plants from tropical to polar latitudes, or the reverse, as a probable, or even possible, event; for although we believe the mean annual temperature of one zone to be transferrible to another, we know that the same climate cannot be so transferred. Whatever be the general temperature of the earth's surface, comparative equability of heat will characterize the tropical regions, while great periodical variations will belong to the temperate, and still more to the polar latitudes. These, and many other peculiarities connected with heat and light, depend on fixed astronomical causes, such as the motion of the earth and its position in relation to the

* Chap. VIII.

sun, and not on those fluctuations of its surface, which may influence the general temperature.

Among many obstacles to such extensive transferences of habitations we must not forget the immense lapse of time required, according to any hypothesis yet suggested, especially that which has appeared to us most feasible, to bring about a considerable change in climate. During a period so vast, the other causes of extirpation, before enumerated by us, would exert so powerful an influence as to prevent all, save a very few hardy species, from passing from equatorial to polar regions, or from the tropics to the pole.

But the power of accommodation to new circumstances is great in certain species, and might enable many to pass from one zone to another, if the mean annual heat of the atmosphere and the ocean were greatly altered. To the marine tribes, especially, such a passage would be possible, for they are less impeded in their migrations, by barriers of land, than are the terrestrial by the ocean. Add to this, that the temperature of the ocean is much more uniform than that of the atmosphere investing the land, so that we may easily suppose that most of the testacea, fish, and other classes, might pass from the equatorial into the temperate regions, if the mean temperature of those regions were transposed, although a second expatriation of these species of tropical origin into the arctic and antarctic circles would probably be impossible.

On the principles above explained, if we found that at some former period, as when, for example, our carboniferous strata were deposited, the same tree-ferns and other plants inhabited the regions now occupied by Europe and Van Diemen's Land, we should suspect that the species in question had, at some antecedent period, inhabited lands within the tropics, and that an increase of the mean annual heat had caused them to emigrate into both the temperate zones. There are no geological data, however, as yet obtained, to warrant the opinion that such identity of species existed in the two hemispheres in the era in question.

Let us now consider more particularly the effect of vicissitudes of climate in causing one species to give way before the increasing numbers of some other.

When temperature forms the barrier which arrests the progress of an animal or plant in a particular direction, the individuals are fewer and less vigorous as they approach the extreme confines of the geographical range of the species. But these stragglers are ready to multiply rapidly on the slightest increase or diminution of heat that may be favourable to them, just as particular insects increase during a hot summer, and certain plants and animals gain ground after a series of congenial seasons.

In almost every district, especially if it be mountainous, there are a variety of species the limits of whose habitations are conterminous, some being unable to proceed farther without encountering too much heat, others too much cold. Individuals, which are thus on the borders of the regions proper to their respective species, are like the out-posts of hostile armies, ready to profit by every slight change of circumstances in their favour, and to advance upon the ground occupied by their neighbours and opponents.

The proximity of distinct climates, produced by the inequalities of the earth's surface, brings species possessing very different constitutions into such immediate contact, that their naturalizations are very speedy whenever opportunities of advancing present themselves. Many insects and plants, for example, are common to low plains within the arctic circle, and to lofty mountains in Scotland and other parts of Europe. If the climate, therefore, of the polar regions were transferred to our own latitudes, the species in question would immediately descend from these elevated stations to overrun the low grounds. Invasions of this kind, attended by the expulsion of the pre-occupants, are almost instantaneous, because the change of temperature not only places the one species in a more favourable position, but renders the others sickly and almost incapable of defence.

These changes inconsistent with the theory of transmutation.—Lamarck appears to have speculated on the modifications to which every variation of external circumstances might give rise in the form and organization of species, as if he had indefinite periods of time at his command, not sufficiently reflecting that revolutions in the state of the habitable earth, whether by changes of climate or any other condition, are attended by still greater fluctuations in the relative condition of contemporary species. They can avail themselves of these alterations in their favour instantly, and augment their numbers to the injury of some other species; whereas the supposed transmutations are only assumed to be brought about by slow and insensible degrees, and in a lapse of ages, the duration of which is beyond the reach of human conception. Even if we thought it possible that the palm or the elephant, which now flourish in equatorial regions, could ever learn to bear the variable seasons of our temperate zone, or the rigours of an arctic winter, we should, with no less confidence, affirm, that they must perish before they had time to become habituated to such new circumstances. That they would be supplanted by other species at each variation of climate, may be inferred from what we have before said of the known local exterminations of species which have resulted from the multiplication of others. Some minute insect, perhaps, might be the cause of destruction to the huge and powerful elephant.

Suppose the climate of the highest part of the woody zone of Etna to be transferred to the sea-shore at the base of the mountain, no botanist would anticipate that the olive, lemon-tree, and prickly pear (*Cactus opuntia*), would be able to contend with the oak and chestnut, which would begin forthwith to descend to a lower level, or that these last would be able to stand their ground against the pine, which would also, in the space of a few years, begin to occupy a lower position. We might form some kind of estimate of the time which might be required for the migrations of these plants; whereas we have no data for concluding that any number of thousands of years

would be sufficient for one step in the pretended metamorphosis of one species into another, possessing distinct attributes and qualities.

This argument is applicable not merely to *climate*, but to any other cause of mutation. However slowly a lake may be converted into a marsh, or a marsh into a meadow, it is evident that before the lacustrine plants can acquire the power of living in marshes, or the marsh-plants of living in a less humid soil, other species, already existing in the region, and fitted for these several stations, will intrude and keep possession of the ground. So if a tract of salt water becomes fresh by passing through every intermediate degree of brackishness, still the marine molluscs will never be permitted to be gradually metamorphosed into fluviatile species; because long before any such transformation can take place by slow and insensible degrees, other tribes, which delight in brackish or fresh water, will avail themselves of the change in the fluid, and will, each in their turn, monopolize the space.

It is idle to dispute about the abstract possibility of the conversion of one species into another, when there are known causes so much more active in their nature, which must always intervene and prevent the actual accomplishment of such conversions. A faint image of the certain doom of a species less fitted to struggle with some new condition in a region which it previously inhabited, and where it has to contend with a more vigorous species, is presented by the extirpation of savage tribes of men by the advancing colony of some civilized nation. In this case the contest is merely between two different *races*, each gifted with equal capacities of improvement—between two varieties, moreover, of a species which exceeds all others in its aptitude to accommodate its habits to the most extraordinary variations of circumstances. Yet few future events are more certain than the speedy extermination of the Indians of North America and the savages of New Holland in the course of a few centuries, when these tribes will be remembered only in poetry and tradition.

CHAPTER XI.

Theory of the successive extinction of species consistent with their limited geographical distribution—The discordance in the opinions of botanists respecting the centres from which plants have been diffused may arise from changes in physical geography subsequent to the origin of living species—Whether there are grounds for inferring that the loss from time to time of certain animals and plants is compensated by the introduction of new species?—Whether any evidence of such new creations could be expected within the historical era, even if they had been as frequent as cases of extinction?—The question whether the existing species have been created in succession can only be decided by reference to geological monuments.

Successive extinction of Species consistent with their limited Geographical Distribution.

We have pointed out in the preceding chapters the strict dependence of each species of animal and plant on certain physical conditions in the state of the earth's surface, and on the number and attributes of other organic beings inhabiting the same region. We have also endeavoured to show that all these conditions are in a state of continual fluctuation, the igneous and aqueous agents remodelling, from time to time, the physical geography of the globe, and the migrations of species causing new relations to spring up successively between different organic beings. We have deduced as a corollary, that the species existing at any particular period must, in the course of ages, become extinct one after the other. 'They must die out,' to borrow an emphatical expression from Buffon, 'because Time fights against them.'

If the views which we have taken are just, there will be no difficulty in explaining why the habitations of so many species are now restrained within exceedingly narrow limits. Every local revolution, such as those contemplated in the preceding chapter, tends to circumscribe the range of some species, while it enlarges that of others; and as we have been led to infer

that new species originate in one spot only, each must require time to diffuse itself over a wide area. The recent origin, therefore, of some species, and the high antiquity of others, may be equally consistent with the general fact of their limited distribution, some being local, because they have not existed long enough to admit of their wide dissemination; others, because circumstances in the animate or inanimate world have occurred to restrict the range which they may once have obtained.

As considerable modifications in the relative levels of land and sea have taken place in certain regions since the existing species were in being, we can feel no surprise that the zoologist and botanist have hitherto found it difficult to refer the geographical distribution of species to any clear and determinate principles, since they have usually speculated on the phenomena, upon the assumption that the physical geography of the globe had undergone no material alteration since the introduction of the species now living. So long as this assumption was made, the facts relating to the geography of plants and animals appeared capricious in the extreme, and by many the subject was pronounced to be so full of mystery and anomalies, that the establishment of a satisfactory theory was hopeless.

Centres from which plants have been diffused.—Some botanists conceived, in accordance with the hypothesis of Willdenow, that mountains were the centres of creation from which the plants now inhabiting large continents have radiated, to which De Candolle and others, with much reason, objected, that mountains, on the contrary, are often the barriers between two provinces of distinct vegetation. The geologist who is acquainted with the extensive modifications which the surface of the earth has undergone in very recent geological epochs, may be able, perhaps, to reconcile both these theories in their application to different regions.

A lofty range of mountains, which is so ancient as to date from a period when the species of animals and plants differed from those now living, will naturally form a barrier between

contiguous provinces; but a chain which has been raised, in great part, within the epoch of existing species, and around which new lands have arisen from the sea within that period, will be a centre of peculiar vegetation.

'In France,' observes De Candolle *, 'the Alps and Cevennes prevent a great number of the plants of the south from spreading themselves to the northward; but it has been remarked that some species have made their way through the gorges of these chains, and are found on their northern sides, principally in those places where they are lower and more interrupted.' Now the chains here alluded to have probably been of considerable height ever since the era when the existing vegetation began to appear, and were it not for the deep fissures which divide them, they might have caused much more abrupt terminations to the extension of distinct assemblages of species.

Parts of the Italian peninsula, on the other hand, have gained a considerable portion of their present height since a majority of the marine species now inhabiting the Mediterranean, and probably, also, since the terrestrial plants of the same region, were in being. Large tracts of land have been added, both on the Adriatic and Mediterranean side, to what originally constituted a much narrower range of mountains, if not a chain of islands running nearly north and south, like Corsica and Sardinia. It may therefore be presumed that the Apennines have been a centre whence species have diffused themselves over the contiguous *lower* and *newer* regions. In this and all analogous situations, the doctrine of Willdenow, that species have radiated from the mountains as from centres, may be well founded.

* Essai Elémentaire, &c., p. 46.

WHETHER THERE ARE GROUNDS FOR INFERRING THAT THE LOSS FROM TIME TO TIME OF CERTAIN ANIMALS AND PLANTS IS COMPENSATED BY THE INTRODUCTION OF NEW SPECIES.

If the reader should infer, from the facts laid before him in the preceding chapters, that the successive extinction of animals and plants may be part of the constant and regular course of nature, he will naturally inquire whether there are any means provided for the repair of these losses? Is it part of the economy of our system that the habitable globe should, to a certain extent, become depopulated both in the ocean and on the land; or that the variety of species should diminish until some new era arrives when a new and extraordinary effort of creative energy is displayed? Or is it possible that new species can be called into being from time to time, and yet that so astonishing a phenomenon can escape the observation of naturalists?

Humboldt has characterized these subjects as among the mysteries which natural science cannot reach; and he observes that the investigation of the origin of beings does not belong to zoological or botanical geography. To geology, however, these topics do strictly appertain; and this science is only interested in inquiries into the state of the animate creation as it now exists, with a view of pointing out its relations to antecedent periods when its condition was different.

Before offering any hypothesis towards the solution of so difficult a problem, let us consider what kind of evidence we ought to expect, in the present state of science, of the first appearance of new animals or plants, if we could imagine the successive creation of species to constitute, like their gradual extinction, a regular part of the economy of nature.

In the first place, it is obviously more easy to prove that a species, once numerously represented in a given district, has ceased to be, than that some other which did not pre-exist has made its appearance—assuming always, for reasons before

stated, that single stocks only of each animal and plant are originally created, and that individuals of new species do not suddenly start up in many different places at once.

So imperfect has the science of natural history remained down to our own times, that, within the memory of persons now living, the numbers of known animals and plants have been doubled, or even quadrupled, in many classes. New and often conspicuous species are annually discovered in parts of the old continent, long inhabited by the most civilized nations. Conscious, therefore, of the limited extent of our information, we always infer, when such discoveries are made, that the beings in question had previously eluded our research; or had at least existed elsewhere, and only migrated at a recent period into the territories where we now find them. It is difficult, even in contemplation, to anticipate the time when we shall be entitled to make any other hypothesis in regard to all the marine tribes, and to by far the greater number of the terrestrial;—such as birds, which possess such unlimited powers of migration; insects which, besides their numbers, are also so capable of being diffused to vast distances; and cryptogamous plants, to which, as to many other classes, both of the animal and vegetable kingdom, similar observations are applicable.

What kind of evidence of such new creations could be expected?—What kind of proofs, therefore, could we reasonably expect to find of the origin at a particular period of a new species?

Perhaps it may be said in reply that, within the last two or three centuries, some forest tree or new quadruped might have been observed to appear suddenly in those parts of England or France which had been most thoroughly investigated;—that naturalists might have been able to show that no such being inhabited any other region of the globe, and that there was no tradition of anything similar having before been observed in the district where it had made its appearance.

Now, although this objection may seem plausible, yet its

force will be found to depend entirely on the rate of fluctuation which we suppose to prevail in the animate world, and on the proportion which such conspicuous subjects of the animal and vegetable kingdoms bear to those which are less known and escape our observation. There are probably more than a million, perhaps two millions of species of plants and animals, exclusive of the microscopic and infusory animalcules, now inhabiting the terraqueous globe. The terrestrial plants, it is supposed, may amount, if fully known, to about 100,000, and the insects to four times that number. To these we have still to add, for the remainder of the terrestrial classes, many of the invertebrated and all the vertebrated animals. As to the aquatic tribes, it remains at present in a great degree mere matter of conjecture what proportion they bear to the denizens of the land; but the habitable surface beneath the waters can hardly be estimated at less than double that of the continents and islands, even admitting that a very considerable area is destitute of life, in consequence of great depth, cold, darkness, and other circumstances. In the late polar expedition it was found that, in some regions, as in Baffin's Bay, there were marine animals inhabiting the bottom at great depths, where the temperature of the water was below the freezing point. That there is life at much greater profundities in warmer regions may be confidently inferred. We have before stated that marine plants not only exist but acquire vivid colours at depths where, to our senses, there would be darkness deep as night.

The ocean teems with life—the class of *polyps* alone are conjectured by Lamarck to be as strong in individuals as insects. Every tropical reef is described as bristling with corals, budding with sponges, and swarming with crustacea, echini, and testacea; while almost every tide-washed rock is carpeted with fuci and studded with corallines, actiniæ, and mollusca. There are innumerable forms in the seas of the warmer zones, which have scarcely begun to attract the attention of the naturalist; and there are parasitic animals without number, three

or four of which are sometimes appropriated to one genus, as to the *Balæna*, for example. Even though we concede, therefore, that the geographical range of marine species is more extensive in general than that of the terrestrial, (the temperature of the sea being more uniform, and the land impeding less the migrations of the oceanic than the ocean those of the terrestrial,) yet we think it most probable that the aquatic species far exceed in number the inhabitants of the land.

Without insisting on this point, we may safely assume, as we before stated, that, exclusive of microscopic beings, there are between one and two millions of species now inhabiting the terraqueous globe; so that if only one of these were to become extinct annually, and one new one were to be every year called into being, more than a million of years would be required to bring about a complete revolution in organic life.

We are not hazarding at present any hypothesis as to the probable rate of change, but none will deny that when we propose as a mere speculation the *annual* birth and the *annual* death of one species on the globe, we imagine no slight degree of instability in the animate creation. If we divide the surface of the earth into twenty regions of equal area, one of these might comprehend a space of land and water about equal in dimensions to Europe, and might contain a twentieth part of the million of species which we will suppose to exist. In this region one species only would, according to the rate of mortality before assumed, perish in twenty years, or only five out of fifty thousand in the course of a century. But as a considerable proportion of the whole would belong to the aquatic classes, with which we have a very imperfect acquaintance, we may exclude them from our consideration, and thus one only might be lost in about forty years among the terrestrial tribes. Now the mammiferous quadrupeds in Great Britain are only to other terrestrial species of organic beings, both plants and animals, in the proportion of about one to two hundred and eighty; and taking this as a rude approximation to a general standard, it would require more than eight thousand years

before it would come to the turn of this conspicuous class to lose one of their number even in a region of the dimensions of Europe.

It is easy, therefore, to conceive, that in a small portion of such an area, in countries, for example, of the size of England and France, periods of much greater duration must elapse before it would be possible to authenticate the first appearance of one of the larger plants and animals, assuming the annual birth and death of one species to be the rate of vicissitude in the animate creation throughout the world.

The observations of naturalists may, in the course of future centuries, accumulate positive data, from which an insight into the laws which govern this part of our terrestrial system may be derived; but in the present deficiency of historical records, we have traced up the subject to that point where geological monuments alone are capable of leading us on to the discovery of ulterior truths. To these, therefore, we must now appeal, carefully examining the strata of recent formation wherein the remains of *living* species, both animal and vegetable, are known to occur. We must study these strata in strict reference to their chronological order as deduced from their superposition, and other relations. From these sources we may learn which of the species, now our contemporaries, have survived the greatest revolutions of the earth's surface; which of them have co-existed with the greatest number of animals and plants now extinct, and which have made their appearance only when the animate world had nearly attained its present condition.

From such data we may be enabled to infer whether species have been called into existence in succession or all at one period; whether singly, or whether by groups simultaneously; whether the antiquity of man be as high as that of any of the inferior beings which now share the planet with him, or whether the human species is one of the most recent of the whole.

To some of these questions we can even now return a satis-

factory answer; and with regard to the rest, we have some data to guide conjecture, and to enable us to speculate with advantage: but it would be premature to anticipate such discussions until we have laid before the reader an ample body of materials amassed by the industry of modern geologists.

CHAPTER XII.

Effects produced by the powers of vitality on the state of the earth's surface—Modifications in physical geography caused by organic beings on dry land inferior to those caused in the subaqueous regions—Why the vegetable soil does not augment in thickness—Organic matter drifted annually to the sea, and buried in subaqueous strata—Loss of nourishment from this source, how supplied—The theory, that vegetation is an antagonist power counterbalancing the degradation caused by running water, untenable—That the igneous causes are the true antagonist powers, and not the action of animal and vegetable life—Conservative influence of vegetation—Its bearing on the theory of the formation of valleys, and on the age of the cones of certain extinct volcanos—Rain diminished by the felling of forests—Distribution of the American forests dependent on the direction of the predominant winds—Influence of man in modifying the physical geography of the globe.

EFFECTS PRODUCED BY THE POWERS OF VITALITY ON THE STATE OF THE EARTH'S SURFACE.

The second branch of our inquiry respecting the changes of the organic world, relates to the effects produced by the powers of vitality on the state of the earth's surface, and on the material constituents of its crust.

By the effects produced on the surface, we mean those modifications in physical geography of which the existence of organic beings is the direct cause,—as when the growth of certain plants covers the slope of a mountain with peat, or converts a swamp into dry land; or when vegetation prevents the soil, in certain localities, from being washed away by running water.

By the agency of the powers of vitality on the material constituents of the earth's crust, we mean those permanent modifications in the composition and structure of new strata, which result from the imbedding therein of animal and vegetable remains. In this case, organic beings may not give rise immediately to any new features in the physical geography of certain tracts, which would not equally have resulted from the

mere operation of inorganic causes; as, for example, if a lake be filling up with sediment, held in suspension by the waters of some river, and with mineral matter precipitated from the waters of springs, the character of the deposits may be modified by aquatic animals and plants, which may convert the earthy particles into shell, peat, and other substances: but the lake may, nevertheless, be filled up in the same time, and the new strata may be deposited in nearly the same order as would have prevailed if its waters had never been peopled by living beings.

In treating of the first division of our subject we may remark, that when we talk of alterations in physical geography, we are apt to think too exclusively of that part of the earth's surface which has emerged from beneath the waters, and with which alone, as terrestrial beings, we are familiar. Here the direct power of animals and plants to cause any important variations is, of necessity, very limited, except in checking the progress of that decay of which the land is the chief theatre. But if we extend our views, and instead of contemplating the dry land we consider that larger portion which is assigned to the aquatic tribes, we discover the immediate influence of the living creation, in imparting varieties of conformation to the solid exterior which the sole agency of inanimate causes would not produce, to be very great.

Thus, when timber is floated into the sea, it is often drifted to vast distances and subsides in spots where there might have been no deposit, at that time and place, if the earth had not been tenanted by living beings. If, therefore, in the course of ages, a hill of wood, or lignite, be thus formed in the subaqueous regions, a change in the submarine geography may be said to have resulted from the action of organic powers. So in regard to the growth of coral reefs: it is probable that almost all the matter of which they are composed is supplied by mineral springs, which we know often rise up at the bottom of the sea, and which, on land, abound throughout volcanic regions thousands of miles in extent. The matter thus con-

stantly given out could not go on accumulating for ever in the waters, but would be precipitated in the abysses of the sea, even if there were no polyps and testacea; but these animals arrest and secrete the carbonate of lime on the summits of submarine mountains, and form reefs many hundred feet in thickness, and hundreds of leagues in length, where, but for them, none might ever have existed.

Why the vegetable soil does not augment in thickness.—If no such voluminous masses are formed on the land, it is not from the want of solid matter in the structure of terrestrial animals and plants, but merely because, as we have so often stated, the continents are those parts of the globe where accessions of matter can scarcely ever take place,—where, on the contrary, the most solid parts already formed are, each in their turn, exposed to gradual degradation. The quantity of timber and vegetable matter which grows in a tropical forest in the course of a century is enormous, and multitudes of animal skeletons are scattered there in the same period, besides innumerable land-shells and other organic substances. The aggregate of these materials might constitute, perhaps, a mass greater in volume than that which is produced in any coral-reef during the same lapse of years; but, although this process should continue on the land for ever, no mountains of wood or bone would be seen stretching far and wide over the country, or pushing out bold promontories into the sea.

The whole solid mass is either devoured by animals, or decomposes, as does a portion of the rock and soil on which the animals and plants are supported. For the decomposition of the strata themselves, especially of their alkaline ingredients and of the organic remains which they so frequently include, is one source from whence running water and the atmosphere may derive the materials which are absorbed by the roots and leaves of plants. Another source is the passage into a gaseous form of even the hardest parts of animals and plants which die and are exposed to putrefy in the air, where they are soon resolved into the elements of which they are composed; and

while a portion of these parts is volatilized, the rest is taken up by rain water and sinks into the earth or flows towards the sea, so that they enter again and again into the composition of different organic beings.

The principal elements found in plants are hydrogen, carbon, and oxygen, so that water and the atmosphere contain all of them, either in their own composition or in solution *. The constant supply of these elements is maintained not only by the putrefaction of animal and vegetable substances, and the decay of rocks before mentioned, but also by the copious evolution of carbonic acid and other gases from volcanos and mineral springs, and by the effects of ordinary evaporation, whereby aqueous vapours are made to rise from the ocean and to circulate round the globe.

It is well known that when two gases of different specific gravity are brought into contact, even though the heavier be the lowermost, they become uniformly diffused by mutual absorption through the whole space which they occupy. By virtue of this law, the heavy carbonic acid finds its way upwards through the lighter air, and conveys nourishment to the lichen which covers the mountain top.

The fact, therefore, that the vegetable mould which covers the earth's surface does not decrease in thickness, will not altogether bear out the argument which was founded upon it by Playfair. This vegetable soil, he observes, consists partly of loose earthy materials easily removed, in the form of sand and gravel, partly of finer particles suspended in the waters, which tinge those of some rivers continually, and those of all occasionally, when they are flooded. The soil, although continually diminished from this cause, 'remains the same in quantity, or at least nearly the same, and must have done so ever since the earth was the receptacle of animal or vegetable life. The soil, therefore, is augmented from other causes,

* See some good remarks on the Formation of Soils, Bakewell's Geology, chap. xviii.

just as much, at an average, as it is diminished by that now mentioned; and this augmentation evidently can proceed from nothing but the constant and slow disintegration of the rocks *.

That the repair of the *earthy* portion of the soil can only proceed, as Playfair suggests, from the decomposition of rocks, may be admitted; but the *vegetable* matter may be supplied, and is actually furnished in a great degree, by absorption from the atmosphere, as we before mentioned, so that in level situations, such as in platforms that intervene between valleys where the action of running water is very trifling, the fine vegetable particles carried off by the rain may be perpetually restored, not by the waste of the rock below, but from the air above.

Organic matter drifted annually to the sea and buried in subaqueous strata.—If we supposed the quantity of food consumed by terrestrial animals, together with the matter absorbed by them in breathing, and the elements imbibed by the roots and leaves of plants, to be derived entirely from that supply of hydrogen, carbon, oxygen, azote, and other elements, given out into the atmosphere and the waters by the putrescence of organic substances, then we might imagine that the vegetable mould would, after a series of years, neither gain nor lose a single particle by the action of organic beings. This conclusion is not far from the truth; but the operation which renovates the vegetable and animal mould is by no means so simple as that here supposed. Thousands of carcasses of terrestrial animals are floated down every century into the sea, and, together with forests of drift-timber, are imbedded in subaqueous deposits, where their elements are imprisoned in solid strata, and may there remain throughout whole geological epochs before they again become subservient to the purposes of life.

Loss of nourishment from this source how supplied.—On the other hand, fresh supplies are derived by the atmosphere, and by running water, as we before stated, from the disintegration

* Illust. of Hutt. Theory, § 103.

of rocks and their organic contents, and from the interior of the earth, from whence all the elements before mentioned, which enter principally into the composition of animals and vegetables, are continually evolved. Even nitrogen has been recently found to be contained very generally in the waters of mineral springs *.

The theory that vegetation is an antagonist power counterbalancing the degradation caused by running water, untenable. —If we suppose that the copious discharge from the nether regions, by springs and volcanic vents, of carbonic acid and other gases, together with the decomposition of rocks, may be just sufficient to counterbalance that loss of matter which, having already served for the nourishment of animals and plants, is annually carried down in organized forms, and buried in subaqueous strata, we believe that we concede the utmost that is consistent with probability. When more is required by a theorist—when we are told that a counterpoise is derived from the same source to that enormous disintegration of solid rock and its transportation to lower levels, which is the annual result of the action of rivers and marine currents, we must entirely withhold our assent. Such an opinion has been recently advanced by an eminent geologist, or we should have deemed it unnecessary to dwell on propositions which appear to us so clear and obvious.

The descriptions which we gave of the degradation yearly going on through the eastern shores of England, and of the enormous weight of solid matter hourly rolled down by the Ganges or the Mississippi, have been represented as extreme cases, calculated to give a partial view of the changes now in progress, especially as we omitted, it is said, to point out the silent but universal action of a great antagonist power, whereby the destructive operations before alluded to are neutralized, and even, in a great degree, counterbalanced.

'Are there,' says Professor Sedgwick, 'no *antagonist* powers

* Dr. Daubeny has ascertained this interesting fact in his late tour on the continent.

in nature to oppose these mighty ravages—no conservative principle to meet this vast destructive agency? The forces of degradation very often of themselves produce their own limitation. The mountain-torrent may tear up the solid rock and bear its fragments to the plain below; but there its power is at an end, and the rolled fragments are left behind to a new action of material elements. And what is true of a single rock, is true of a mountain-chain; and vast regions on the surface of the earth, now only the monuments of spoliation and waste, may hereafter rest secure under the defence of a thick vegetable covering, and become a new scene of life and animation.

'It well deserves remark that the destructive powers of nature act only upon lines, while some of the grand principles of conservation act upon the whole surface of the land. By the processes of vegetable life an incalculable mass of solid matter is absorbed, year after year, from the elastic and non-elastic fluids circulating round the earth, and is then thrown down upon its surface. In this *single* operation there is a *vast counterpoise to all* the agents of destruction. And the deltas of the Ganges and the Mississippi are not solely formed at the expense of the solid materials of our globe, but in part, and I believe also in a considerable part, by one of the great conservative operations by which the elements are made to return into themselves *.'

This is splendid eloquence, full of the energy and spirit that breathes through the whole address:—

> Monte decurrens velut amnis, imbres
> Quem super notas aluere ripas,
> Fervet, immensusque ruit—

but we must pause for a moment, lest we be hurried away by its tide. Let us endeavour calmly to consider whither it would carry us.

If by the elements returning *into themselves* be meant their return to higher levels, it is certainly possible that a fraction of the organic matter which is intermixed with the mud and sand

* Address to the Geological Society on the Anniversary, Feb. 1831, p. 24.

deposited in alternate strata in the delta of the Ganges, may have been derived by the leaves and roots of plants from such aqueous vapour, carbonic acid, and other gases, as had ascended into the atmosphere from *lower* regions, and which were not, therefore, derived from the waste of rocks and their organic contents, or from the putrescence of vegetables previously nourished from these sources. This fraction, and this alone, may then be deducted from the mass of solid matter annually transported into the Bay of Bengal, and what remains, whether organic or inorganic, will be the measure of the degradation which thousands of torrents in the Himalaya mountains, and many rivers of other parts of India, bring down in a single year. Even in this case it will be found that the sum of the force of vegetation can merely be considered as having been in a slight degree *conservative*, retarding the waste of land, and not acting as an antagonist power.

But the untenable nature of the doctrine which we are now controverting may be set in a clearer light by examining the present state of the earth's surface, on which it is declared that ‘an incalculable mass of solid matter is thrown down year after year,’ in such a manner as to form a counterpoise to the agents of decay. Is it not a fact that the vegetable mould is seldom more than a few feet in thickness, and that it often does not exceed a few inches? Do we find that its volume is more considerable on those parts of our continents which we can prove, by geological data, to have been elevated at more ancient periods, and where there has been the greatest time for the accumulation of vegetable matter, produced throughout successive zoological epochs? On the contrary, are not these higher and older regions more frequently denuded, so as to expose the bare rock to the action of the sun and air?

Do we find in the torrid zone, where the growth of plants is most rank and luxurious, that accessions of matter due to their agency are most conspicuous on the surface of the land? On the contrary, is it not there where the vegetation is most active that, for reasons to be explained in the next chapter, even those

superficial peat mosses are unknown which cover a large area in some parts of our temperate zone? If the operation of animal and vegetable life could restore to the general surface of the continents a portion of the elements of those disintegrated rocks, of which such enormous masses are swept down annually into the sea, along particular river-courses and lines of coast, the effects would have become ere now most striking; and would have constituted one of the most leading features in the structure and composition of our continents. All the great steppes and table-lands of the world, where the action of running water is feeble, would have become the grand repositories of organic matter, accumulated without that intermixture of sediment which so generally characterizes the subaqueous strata.

Even the formation of peat in certain districts where the climate is cold and moist, the only case, perhaps, which affords the shadow of a support to the theory under consideration, has not in every instance a conservative tendency. A peat-moss often acts like a vast sponge, absorbing water in large quantities, and swelling to the height of many yards above the surrounding country. The turfy covering of the bog serves, like the skin of a bladder, to retain for a while the fluid within, and a violent inundation sometimes ensues when that skin bursts, as has often happened in Ireland, and many parts of the continent. Examples will be mentioned by us in a subsequent chapter, where the Stygian torrent has hollowed out ravines, and borne along rocks and sand, in countries where such ravages could not have happened but for the existence of peat. Here, therefore, the force of vegetation accelerates the rate of decay of land, and the solid matter swept down to lower levels during such floods counterbalances, to a certain degree, the accessions of vegetable mould which may accrue to the land by the growth of peat.

We may explain more clearly the kind of force which we imagine vegetation to exert, by comparing it to the action of frost, which augments the height of some few Alpine summits by causing a mass of perpetual snow to lodge thereon, or fills

up some valleys with glaciers; but although by this process of congelation the rain-water that has risen by evaporation from the sea is retained for a while in a solid form upon the land, and although some elevated spots may be protected from waste by a constant covering of ice, yet, by the sudden melting of snow and ice, the degradation of rocks is often accelerated, Although every year fresh snow and ice are formed, as also more vegetable and animal matter, yet there is no increase; the one melts, the other putrefies, or is drifted down to the sea by rivers. If this were not the case, frost might be considered as an antagonist power, as well as the action of animal and vegetable life, and these by their combined energy might restore to continents a portion of that solid matter which is swept down into the sea from mountains and wasting cliffs. By the aid of such machinery might a theorist repair the losses of the solid land, sand and rocky fragments being carried down annually to the subaqueous regions from hills of granite, limestone, and shale, while vegetation and frost might raise new mountains, which, like the cliffs in Eschscholtz's Bay, might consist of icebergs intermixed with vegetable mould.

That the igneous causes are the true antagonist powers, and not the action of animal and vegetable life.—We have stated in a former volume that, in the known operation of the *igneous* causes, a real antagonist power is found which may counterbalance the levelling action of running water; and there seems no good reason for presuming that the upheaving and depressing force of earthquakes, together with the heaving up of ejected matter by volcanos, may not be fully adequate to restore the superficial inequalities which rivers and oceanic currents annually tend to lessen. If a counterpoise be derived from this source, the quantity and elevation of land above the sea may for ever remain the same, in spite of the action of the aqueous causes, which, if thus counteracted, may never be able to reduce the surface of the earth more nearly to a state of equilibrium than that which it has now attained; and, on

the other hand, the force of the aqueous agents themselves might thus continue for ever unimpaired. This permanence of the intensity of the powers now in operation would account for any amount of disturbance or degradation of the earth's crust, so far as the *mere quantity* of movement or decay is concerned; provided only that indefinite periods of time are contemplated.

As to the *intensity* of the disturbing causes at particular epochs, their effects have as yet been studied for too short a time to enable us fully to compare the signs of ancient convulsions with the permanent monuments left in the earth's crust by the events of the last few thousand years. But, notwithstanding the small number of changes which have been witnessed and carefully recorded, observation has at least shown that our knowledge of the extent of the subterranean agency, as now developed from time to time, is in its infancy; and there can be no doubt that great partial mutations in the structure of the earth's crust are brought about in volcanic regions, without any interruption to the general tranquillity of the habitable surface.

Some geologists point to particular cases of enormous dislocation of ancient date, and confessedly not of frequent occurrence, where shifts in the strata of 2000 feet and upwards appear to have been produced suddenly and at one effort. But they have been at no pains to prove that similar consequences could not result from earthquakes such as have happened within the last 3000 years. They have usually proceeded on *à priori* reasoning to assume that such convulsions were paroxysmal, and attended by catastrophes such as have never occurred in modern times. It would be irrelevant to the subject immediately under consideration to enter into a long digression on these topics, but we may remind the reader that the subsidence of the quay at Lisbon to the depth of 600 feet only gave rise to a slight whirlpool; and we may thence infer the possibility of a sinking down or elevation four or five times as great, especially in deeper seas, without any

superficial disturbance unparalleled in the events of the last century.

If a certain sect of geologists were as anxious to reconcile the actual and former course of nature as they are eager to contrast them, they would perceive that the effects witnessed by us of subterranean action on supramarine land may not be a type of those which the submerged rocks undergo, and they would proceed with more caution when reasoning from a comparison between the accumulated results of disturbing causes in the immensity of past time, and those which are recorded in the meagre annals of a brief portion of the human era.

The same rash generalizations which are now made respecting eras of paroxysmal violence and chaotic derangement led formerly to the doctrines of universal formations, the improbability of which might have been foreseen by a slight reference to the causes now in operation.

To the same modes of philosophizing we may ascribe the unwillingness of some naturalists to admit that all the fossil species are not the same as those now living on the globe; whereas, if the facts and reasonings set forth in a former part of this volume, respecting the present instability of the organic creation, be just, it might always *à priori* have been seen that the species inhabiting the planet at two periods very remote could hardly be identical.

In our view of the Huttonian theory, we pointed out as one of its principal defects the assumed want of synchronism in the action of the great antagonist powers—the introduction, first, of periods when continents gradually wasted away, and then of others when new lands were elevated by violent convulsions. In order to have a clear conception of the working of such a system, let the reader suppose the earthquakes and volcanic eruptions of the Andes to be suspended for a million of years, and sedimentary deposits to accumulate throughout the whole of that period, as they now accumulate at the mouths of the Orinoco and Amazon, and along the inter-

vening coast. Then let a period arrive when the subterranean power, which had obtained no vent during those ten thousand centuries, should escape suddenly in one tremendous explosion.

It is natural that geologists who reject such portions of the Huttonian theory as we embrace should cling fondly to those parts which we deem unsound and unphilosophical. They have accordingly selected the distinctness of the periods when the antagonist forces are developed, as a principle peculiarly worthy of implicit faith. For this reason they have declined making any strenuous effort to account for those violations of continuity in the series of geological phenomena which are exhibited in large but limited regions; and which we have hinted may admit of explanation by the shifting of the volcanic foci, without the necessity of calling into our aid any hypothetical eras of convulsion.

In the oriental cosmogonies, as we have seen, both the physical and moral worlds were represented to be subject to gradual deterioration, until a crisis arrived when they were annihilated, or reverted to a state of chaos; there had been alternating periods of tranquillity and disorder—an endless vicissitude of destructions and renovations of the globe.

In the spirit of this antique philosophy, some modern geologists conceive that nature, after long periods of repose, is agitated by fits of 'feverish spasmodic energy, during which her very frame-work is torn asunder *;' these paroxysms of internal energy are accompanied by the sudden elevation of mountain chains, 'followed by mighty waves desolating whole regions of the earth †;' and, according to some authors, whole races of organic beings are thus suddenly annihilated.

It was to be expected that when, in opposition to these favourite dogmas, we enumerated the subterranean catastrophes of the last one hundred and forty years, pointing out how defective were our annals, and called on geologists to multiply

* Prof. Sedgwick, Anniv. Address, &c. 1831, p. 35. † Ibid.

the amount of disturbances arising from this source by myriads of ages during the existence of successive races of organic beings, that we should provoke some vehement expostulation. We could not hope that the self-appointed guardians of Nature's slumber would allow us with impunity thus suddenly to intrude upon her rest, or that they would fail to resent so rude an attempt to rouse her from the torpor into which she had been lulled by their hypothesis. We were prepared to see our proofs and authorities severely sifted, our inferences rigorously scrutinized; but we never supposed it possible that our adversaries would set up 'as a vast counterpoise to all the agents of destruction,' a cause so nugatory as 'the single operation of vegetable life *.'

Conservative influence of vegetation.—As it will appear from what we before said that vegetation cannot act as an antagonist power amid the mighty agents of change which are always modifying the surface of the globe, let us next inquire how far its influence is conservative,—how far it may retard the levelling power of running water, which it cannot oppose, much less counterbalance.

It is well known that a covering of herbage and shrubs may protect a loose soil from being carried away by rain, or even by the ordinary action of a river, and may prevent hills of loose sand from being blown away by the wind. For the roots bind together the separate particles into a firm mass, and the leaves intercept the rain-water, so that it dries up gradually instead of flowing off in a mass and with great velocity. The old Italian hydrographers make frequent mention of the increased degradation which has followed the clearing away of natural woods in several parts of Italy. A remarkable example was afforded in the Upper Val d'Arno, in Tuscany, on the removal of the woods clothing the steep declivities of the hills by which that valley is bounded. When the ancient forest laws were abolished by the Grand Duke Joseph, during the last century, a considerable tract of surface in the Cassentina (the Clausen-

* Prof. Sedgwick's Anniv. Address, Feb. 1831, p. 24.

tinium of the Romans) was denuded, and, immediately, the quantity of sand and soil washed down into the Arno increased enormously. Frisi, alluding to such occurrences, observes, that as soon as the bushes and plants were removed, the waters flowed off more rapidly, and, in the manner of floods, swept away the vegetable soil *.

Its bearing on the formation of valleys, and on the age of the cones of certain extinct volcanos.—This effect of vegetation is of high interest to the geologist, when he is considering the formation of those valleys which have been principally due to the action of rivers. The spaces intervening between valleys, whether they be flat or ridgy, when covered with vegetation, may scarcely undergo the slightest waste, as the surface may be protected by the green sward of grass; and this may be renewed, in the manner before described, from elements derived from rain-water and the atmosphere. Hence, while the river is continually bearing down matter in the alluvial plain, and undermining the cliffs on each side of every valley, the height of the intervening rising grounds may remain stationary.

In this manner a cone of loose scoriæ, sand and ashes, such as Monte Nuovo, may, when it has once become densely clothed with herbage and shrubs, suffer scarcely any further dilapidation; and the perfect state of the cones of hundreds of extinct volcanos in France, Campania, Sicily, and elsewhere, may prove nothing whatever, either as to their relative or absolute antiquity. We may be enabled to infer from the integrity of such conical hills of incoherent materials, that no flood can have passed over the countries where they are situated since their formation; but the atmospheric action alone in spots where there happen to be no torrents, and where the surface was clothed with vegetation, could scarcely in any lapse of ages have destroyed them.

During a late tour in Spain I was surprized to see a district of gently undulating ground in Catalonia, consisting of

* Treatise on Rivers and Torrents, p. 5, Garston's translation.

red and grey sandstone, and in some parts of red marl, almost entirely denuded of herbage, while the roots of the pines, holm oaks, and some other trees were half exposed, as if the soil had been washed away by a flood. Such is the state of the forests, for example, between Orista and Vich, and near San Lorenzo. Being at length overtaken by a violent thunder-storm, in the month of August, I saw the whole surface, even the highest levels of some flat-topped hills, streaming with mud, while on every declivity the devastation of torrents was terrific. The peculiarities in the physiognomy of the district were at once explained, and I was taught that in speculating on the greater effects which the direct action of rain may once have produced on the surface of certain parts of England, we need not revert to periods when the heat of the climate was *tropical*.

In the torrid zone the degradation of land is generally more rapid, but the waste is by no means proportioned to the superior quantity of rain or the suddenness of its fall, the transporting power of water being counteracted by a greater luxuriance of vegetation. A geologist who is no stranger to tropical countries observes, that the softer rocks would speedily be washed away in such regions, if the numerous roots of plants were not matted together in such a manner as to produce considerable resistance to the destructive power of the rains. The parasitical and creeping plants also entwine in every possible direction so as to render the forests nearly impervious, and the trees possess forms and leaves best calculated to shoot off the heavy rains, which when they have thus been broken in their fall are quickly absorbed by the ground beneath, or when thrown into the drainage depressions give rise to furious torrents *.

Rain diminished by felling of forests.—The felling of forests has been attended, in many countries, by a diminution of rain, as in Barbadoes and Jamaica †. For in tropical

* De la Beche, Geol. Man. p. 184. † Phil. Trans. vol. ii. p. 294.

countries, where the quantity of aqueous vapour in the atmosphere is very great, but where, on the other hand, the direct rays of the sun have immense power, any impediment to the free circulation of air, or any screen which shades the earth from the solar rays, becomes a powerful cause of humidity, and wherever dampness and cold have begun to be generated by such causes, the condensation of vapour continues. The leaves moreover of all plants are alembics, and some of those in the torrid zone have a remarkable power of distilling water, thus contributing to prevent the earth from becoming parched up.

Distribution of the American forests dependent on the direction of the predominant winds.—There can be no doubt that the state of the climate, especially the humidity of the atmosphere, influences vegetation, and that, in its turn, vegetation reacts upon the climate; but some writers seem to have attributed too much importance to the influence of forests, particularly those of America, as if they were the primary cause of the moisture of the climate.

The theory of a modern author on this subject, 'that forests exist in those parts of America only where the predominant winds carry with them a considerable quantity of moisture from the ocean,' seems far more rational. In all countries, he says, 'having a summer heat exceeding 70°, the presence or absence of natural woods, and their greater or less luxuriance, may be taken as a measure of the amount of humidity, and of the fertility of the soil. Short and heavy rains, in a warm country, will produce grass, which, having its roots near the surface, springs up in a few days, and withers when the moisture is exhausted; but transitory rains, however heavy, will not nourish trees, because, after the surface is saturated with water, the rest runs off, and the moisture lodged in the soil neither sinks deep enough, nor is in sufficient quantity to furnish the giants of the forest with the necessary sustenance. It may be assumed that twenty inches of rain falling moderately, or at intervals, will leave a greater permanent supply in the soil than

forty inches falling, as it sometimes does in the torrid zone, in as many hours *.'

'In all regions,' he continues, 'where ranges of mountains intercept the course of the constant or predominant winds, the country on the windward side of the mountains will be moist, and that on the leeward dry, and hence parched deserts will generally be found on the west side of countries within the tropics, and on the east side of those beyond them, the prevailing winds in these cases being generally in opposite directions. On this principle, the position of forests in North and South America may be explained. Thus, for example, in the region within the thirtieth parallel, the moisture swept up by the trade-wind from the Atlantic is precipitated in part upon the mountains of Brazil, which are but low and so distributed as to extend far into the interior. The portion which remains is borne westward, and, losing a little as it proceeds, is at length arrested by the Andes, where it falls down in showers on their summits. The aërial current, now deprived of all the humidity with which it can part, arrives in a state of complete exsiccation at Peru, where, consequently, no rain falls. In the same manner the Ghauts in India, a chain only three or four thousand feet high, intercept the whole moisture of the atmosphere, having copious rains on their windward side, while on the other the weather remains clear and dry. The rains in this case change regularly from the west side to the east, and vice versâ, *with the monsoons*. But in the region of America, beyond the thirtieth parallel, the Andes serve as a screen to intercept the moisture brought by the prevailing winds from the Pacific Ocean; rains are copious on their summits, and in Chili on their *western* declivities; but none falls on the plains to the *eastward*, except occasionally when the wind blows from the Atlantic †.'

We have been more particular in explaining these views,

* Maclaren, art. America, Encyc. Britannica.

† Ibid., where the position of the American forests, in accordance with this theory, is laid down in a map.

because they appear to us to place in a true light the dependence of vegetation on climate, notwithstanding the reciprocal action which each exerts on the other, the humidity being increased, and more uniformly diffused throughout the year, by the gradual spreading of wood.

INFLUENCE OF MAN IN MODIFYING THE PHYSICAL GEOGRAPHY OF THE GLOBE.

Before concluding this chapter, we must offer a few observations on the influence of man in modifying the physical geography of the globe, for we must class his agency among the powers of organic nature.

The modifications of the surface, resulting from human agency, are only on a considerable scale when we have obtained so much knowledge of the working of the laws of nature as to be able to use them as instruments to effect our purposes. We must command nature by obeying her laws, according to the saying of the philosopher, and for this reason we can never materially interfere with any of the great changes which either the aqueous or igneous causes are bringing about on the earth. In vain would the inhabitants of Italy strive to prevent the tributaries of the Po and Adige from bearing down, annually, an immense volume of sand and mud from the Alps and Apennines; in vain would they toil to reconvey to the mountains the mass torn from them year by year, and deposited in the form of sediment in the Adriatic. But they have, nevertheless, been able to vary the distribution of this sediment over a considerable area, by embanking the rivers, and preventing the sand and mud from being spread by annual inundations over the plains.

We have explained how the form of the delta of the Po has been altered by this system of embankment, and how much more rapid, in consequence of these banks, have been the accessions of land at the mouths of the Po and Adige within the last twenty centuries. There is a limit, however, to these modifications, since the danger of floods augments with the

increasing height of the river-beds, while the expense of maintaining the barrier is continually enhanced, as well as the difficulty of draining the low surrounding country.

In the Ganges, says Major R. H. Colebrooke, no sooner is a slight covering of soil observed on a new sand-bank, than the island is cultivated; water-melons, cucumbers, and mustard, become the produce of the first year, and rice is often seen growing near the water's edge, where the mud is in large quantity. Such islands may be swept away before they have acquired a sufficient degree of stability to resist permanently the force of the stream; but if, by repeated additions of soil, they acquire height and firmness, the natives take possession, and bring over their families, cattle, and effects. They choose the highest spots for the sites of villages, where they erect their dwellings with as much confidence as they would do on the main land; for, although the foundation is sandy, the uppermost soil, being interwoven with the roots of grass and other plants, and hardened by the sun, is capable of withstanding all attacks of the river. These islands often grow to a considerable size, and endure for the lives of the new possessors, being only at last destroyed by the same gradual process of undermining and encroachment to which the banks of the Ganges are subject *.

If Bengal were inhabited by a nation more advanced in opulence and agricultural skill, they might, perhaps, succeed in defending these possessions against the ravages of the stream for much longer periods; but no human power could ever prevent the Ganges or the Mississippi from making and unmaking islands. By fortifying one spot against the set of the current, its force is only diverted against some other point; and, after a vast expense of time and labour, the property of individuals may be saved, but no addition would thus be made to the sum of productive land. It may be doubted whether any system could be devised so conducive to *national* wealth as the simple plan pursued by the peasants of Hindostan, who,

* Asiatic Trans., vol. vii.

wasting no strength in attempts to thwart one of the great operations of nature, permit the alluvial surface to be perpetually renovated, and find their losses in one place compensated in some other, so that they continue to reap an undiminished harvest from a virgin soil.

To the geologist the Gangetic islands and their migratory colonies may present an epitome of the globe as tenanted by man. For during every century we cede some territory which the earthquake has sunk, or the volcano has covered by its fiery products, or which the ocean has devoured by its waves. On the other hand, we gain possession of new lands, which rivers, tides, or volcanic ejections have formed, or which subterranean causes have upheaved from the deep. Whether the human species will outlast the whole or a great part of the continents and islands now seen above the waters, is a subject far beyond the reach of our conjectures; but thus much may be inferred from geological data,—that if such should be its lot, it will be no more than has already fallen to pre-existing species, some of which have, ere now, outlived the form and distribution of land and sea which prevailed at the era of their birth.

We have before shown, when treating of the excavation of new estuaries in Holland by inroads of the ocean, as also of the changes on our own coasts, that although the conversion of sea into land by artificial labours may be great, yet it must always be in subordination to the great movements of the tides and currents. If, in addition to the assistance obtained by parliamentary grants for defending Dunwich from the waves, all the resources of Europe had been directed to the same end, the existence of that port might possibly have been prolonged for many centuries. But, in the meantime, the current would have continued to sweep away portions from the adjoining cliffs on each side, rounding off the whole line of coast into its present form, until at length the town must have projected as a narrow promontory, becoming exposed to the irresistible fury of the waves.

It is scarcely necessary to observe, that the control which

man can exert over the igneous agents is less even than that which he may obtain over the aqueous. He cannot modify the upheaving or depressing force of earthquakes, or the periods or degree of violence of volcanic eruptions ; and on these causes the inequalities of the earth's surface, and, consequently, the shape of the sea and land, appear mainly to depend. The utmost that man can hope to effect in this respect, is occasionally to divert the course of a lava-stream, and to prevent the burning matter, for a season at least, from overwhelming a city, or other fruit of human industry.

No application, perhaps, of human skill and labour tends so greatly to vary the state of the habitable surface, as that employed in the drainage of lakes and marshes, since not only the *stations* of many animals and plants, but the general climate of a district, may thus be modified. It is also a kind of alteration to which it is difficult, if not impossible, to find anything analogous in the agency of inferior beings. For we ought always, before we decide that any part of the influence of man is novel and anomalous, carefully to consider all the powers of other animate agents which may be limited or superseded by him. Many who have reasoned on these subjects seem to have forgotten that the human race often succeeds to the discharge of functions previously fulfilled by other species; a topic on which we have already offered some hints, when explaining how the distribution and numbers of each species are dependent on the state of contemporary beings.

Suppose the growth of some of the larger terrestrial plants, or, in other words, the extent of forests, to be diminished by man, and the climate to be thereby modified, it does not follow that this kind of innovation is unprecedented. It is a change in the state of the vegetation, and such may often have been the result of the entrance of new species into the earth. The multiplication, for example, of certain insects in parts of Germany, during the last century, destroyed more trees than man, perhaps, could have felled during an equal period.

It is a curious fact, to which we shall again advert, that the

sites of many European forests, cut down since the time of the Romans, have become peat-mosses; and thus a permanent change has been effected in these regions. But other woods, blown down by winds, in the same countries, have also become peat-bogs; so that, although man may have accelerated somewhat the change, yet it may be doubted whether other animate and inanimate causes might not, without his interference, have produced similar results. The atmosphere of our latitudes may have been slowly and insensibly cooling down since the ancient forests began to grow, and the time may have arrived when slight accidents were sufficient to cause the decrease of trees, and the usurpation of their site by other plants.

We do not pretend to decide how far the power of man, to modify the surface, may differ in kind or degree from that of other living beings, but we suspect that the problem is more complex than has been imagined by many who have speculated on such topics. If new land be raised from the sea, the greatest alteration in its physical condition, which could ever arise from the influence of organic beings, would probably be produced by the first immigration of terrestrial plants, whereby the tract would become covered with vegetation. The change next in importance would seem to be when animals enter, and modify the proportionate numbers of certain species of plants. If there be any anomaly in the intervention of man, in farther varying the relative numbers in the vegetable kingdom, it may not so much consist in the kind or absolute quantity of alteration, as in the circumstance that *a single species,* in this case, would exert, by its superior power and universal distribution, an influence equal to that of hundreds of other terrestrial animals.

If we inquire whether man, by his direct removing power, or by the changes which he may give rise to indirectly, tends, upon the whole, to lessen or increase the inequalities of the earth's surface, we shall incline, perhaps, to the opinion that he is a levelling agent. He conveys upwards a certain quantity of materials from the bowels of the earth in mining operations;

but, on the other hand, much rock is taken annually from the land, in the shape of ballast, and afterwards thrown into the sea, whereby, in spite of prohibitory laws, many harbours, in various parts of the world, have been blocked up. We rarely transport heavy materials to higher levels, and our pyramids and cities are chiefly constructed of stone brought down from more elevated situations. By ploughing up thousands of square miles, and exposing a surface for part of the year to the action of the elements, we assist the abrading force of rain, and destroy the conservative effects of vegetation.

But the aggregate force exerted by man is truly insignificant, when we consider the operations of the great physical causes, whether aqueous or igneous, in the inanimate world. If all the nations of the earth should attempt to quarry away the lava which flowed during one eruption from the Icelandic volcanos in 1783 and the two following years, and should attempt to consign it to the deepest abysses of the ocean, wherein it might approach most nearly to the profundities from which it rose in the volcanic vent, they might toil for thousands of years before their task was accomplished. Yet the matter borne down by the Ganges and Burrampooter, in a single year, probably very much exceeds, in weight and volume, the mass of Icelandic lava produced by that great eruption *.

* Vol. i. ch. xiv.

CHAPTER XIII.

Effects produced by the action of animal and vegetable life on the material constituents of the earth's crust—Imbedding of organic remains in deposits on emerged land—Growth of Peat—Peat abundant in cold and humid climates—Site of many ancient forests in Europe now occupied by peat—Recent date of many of these changes—Sources of Bog Iron-ore—Preservation of animal substances in peat—Causes of its antiseptic property—Miring of quadrupeds—Bursting of the Solway Moss—Bones of herbivorous quadrupeds found in peat—Imbedding of animal remains in caves and fissures—Formation of bony breccias—Human bones and pottery intermixed with the remains of extinct quadrupeds in caves in the South of France—Inferences deducible from such associations.

EFFECTS PRODUCED BY THE ACTION OF ANIMAL AND VEGETABLE LIFE ON THE MATERIAL CONSTITUENTS OF THE EARTH'S CRUST.

We now come to the second subdivision of the inquiry explained in the preceding chapter,—the consideration of the permanent modifications produced in the material constituents of the earth's crust, by the action of animal and vegetable life.

New mineral compounds, such as might never have existed in this globe but for the action of the powers of vitality, are annually formed, and made to enter into deposits accumulated both above and beneath the waters. Although we can neither explain nor imitate the processes of animal and vegetable life whereby those substances are produced, yet we can investigate the laws by virtue of which organic matter becomes imbedded in new strata,—sometimes imparting to them a peculiar mineral composition,—sometimes leaving durable impressions and casts of the forms of animate beings in rocks, so as to modify their structure and appearance.

Division of the subject.—It has been well remarked by M. Constant Prevost, that the effects of geological causes are divisible into two great classes; those produced on the surface during the immersion of land beneath the waters, and those

which take place after its emersion. Agreeably to this classification we shall consider, first, in what manner animal and vegetable remains become included and preserved in solid deposits on emerged land, or that part of the surface which is not *permanently* covered by water, whether of the sea or lakes; secondly, the manner in which organic remains become imbedded in subaqueous deposits.

Under the first division we shall treat of the following topics:—1st, the growth of peat, and the preservation of vegetable and animal remains therein;—2ndly, the preservation of animal remains in stalactite, and in the mud of caves and fissures;—3dly, the burying of organic remains in alluvium and the ruins of land-slips;—4thly, of the same in blown sand;—5thly, of the same in volcanic ejections, and alluvions composed of volcanic productions.

The growth of Peat and the preservation of Vegetable and Animal Remains therein.

The generation of peat, when not completely under water, is confined to moist situations, where the temperature is low, and where vegetables may decompose without putrefying. It may consist of any of the numerous plants which are capable of growing in such *stations;* but a species of moss (*Sphagnum palustre*) constitutes a considerable part of the peat found in marshes of the north of Europe; this plant having the property of throwing up new shoots in its upper part, while its lower extremities are decaying *. Reeds, rushes and other aquatic plants may usually be traced in peat, and their organization is often so entire, that there is no difficulty in discriminating the distinct species.

Analysis of Peat.—In general, says Sir H. Davy, one hundred parts of dry peat contain from sixty to ninety-nine parts of matter destructible by fire, and the residuum consists of earths usually of the same kind as the substratum of clay, marl,

* For a catalogue of the plants which contribute to the generation of peat, see Dr. Rennie on Peat, pp. 171—178. Dr. Macculloch's Western Isles, vol. i. p. 129.

gravel, or rock on which they are found, together with oxide of iron. 'The peat of the chalk counties of England,' observes the same writer, 'contains much gypsum; but I have found very little in any specimens from Ireland or Scotland, and in general these peats contain very little saline matter *.' From the researches of Dr. Macculloch, it appears that peat is intermediate between simple vegetable matter and lignite, the conversion of peat to lignite being gradual, and being brought about in a great lapse of time by the prolonged action of water †.

Peat abundant in cold and humid climates.—Peat is sometimes formed on a declivity in mountainous regions where there is much moisture, but in such situations it rarely if ever exceeds four feet in thickness. In bogs, and in low grounds into which alluvial peat is drifted, it is found forty feet thick and upwards, but in such cases it generally owes one-half of its volume to the water which it contains. It has seldom, if ever, been discovered within the tropics, and it rarely occurs in the valleys even in the south of France and Spain. It abounds more and more in proportion as we advance farther from the equator, and becomes not only more frequent but more inflammable in northern latitudes ‡; the cause of which may probably be that the carbonic acid and hydrogen, which are the most inflammable parts, do not readily assume the gaseous form in a cold atmosphere.

Extent of surface covered by peat.—There is a vast extent of surface in Europe covered with peat, which in Ireland is said to extend over a tenth of the whole island. One of the mosses on the Shannon is described by Dr. Boates to be fifty miles long, by two or three broad; and the great marsh of Montoire, near the mouth of the Loire, is mentioned by Blavier as being more than fifty leagues in circumference. It is a curious and well-ascertained fact that many of these mosses of the north of Europe occupy the place of immense forests

* Irish Bog Reports, p. 209. † System of Geology, vol. ii. p. 353.
‡ Rev. Dr. Rennie on Peat, p. 260.

of pine and oak, which have many of them disappeared within the historical era. Such changes are brought about by the fall of trees and the stagnation of water, caused by their trunks and branches obstructing the free drainage of the atmospheric waters, and giving rise to a marsh. In a warm climate such decayed timber would immediately be removed by insects, or by putrefaction; but, in the cold temperature now prevailing in our latitudes, many examples are recorded of marshes originating in this source. Thus, in Mar forest in Aberdeenshire, large trunks of Scotch fir, which had fallen from age and decay, were soon immured in peat formed partly out of their perishing leaves and branches, and in part from the growth of other plants. We also learn that the overthrow of a forest by a storm, about the middle of the seventeenth century, gave rise to a peat-moss near Lochbroom, in Ross-shire, where, in less than half a century after the fall of the trees, the inhabitants dug peat*. Dr. Walker mentions a similar change when, in the year 1756, the whole wood of Drumlanrig was overset by the wind. Such events explain the occurrence, both in Britain and on the continent, of mosses where the trees are all broken within two or three feet of the original surface, and where their trunks all lie in the same direction †.

Nothing is more common than the occurrence of buried trees at the bottom of the Irish peat-mosses, as also in most of those of England, France, and Holland; and they have been so often observed with parts of their trunks standing erect, and with their roots fixed to the sub-soil, that no doubt can be entertained of their having generally grown on the spot. They consist for the most part of the fir, the oak, and the birch; where the sub-soil is clay, the remains of oak are the most abundant; where sand is the substratum, fir prevails. In the marsh of Curragh, in the Isle of Man, vast trees are discovered standing firm on their roots, though at the depth of eighteen or twenty feet below the surface. Some naturalists have desired to refer the imbedding of timber in peat-mosses to aqueous trans-

* Dr. Rennie's Essays, p. 65.

† Ibid. p. 30.

portation, since rivers are well known to float wood into lakes; but the facts above mentioned show that, in numerous instances, such an hypothesis is inadmissible. It has moreover been observed that in Scotland, as also in many parts of the continent, the largest trees are found in those peat-mosses which lie in the least elevated regions, and that the trees are proportionably smaller in those which lie at higher levels; from which fact De Luc and Walker have both inferred that the trees grew on the spot, for they would naturally attain a greater size in lower and warmer levels. The leaves also, and fruits of each species, are continually found immersed in the moss along with the parent trees, as, for example, the leaves and acorns of the oak, the cones and leaves of the fir, and the nuts of the hazel.

Sometimes, in the same bog, a stratification is observed of different kinds of wood, oak being found in the lowermost stratum, and birch and hazel in a second bed above. Sometimes still higher, a stratum, containing alder with the twigs of the bog myrtle (*Myrica galæ*), have been found; the succession of strata, in this instance, indicating a gradual conversion of a dry tract into a swamp, and lastly a peat-moss.

The durability of pine-wood, which in the Scotch peat-mosses exceeds that of the birch and oak, is due to the great quantity of turpentine which it contains, and which is so abundant that the fir-wood from bogs is used by the country people, in parts of Scotland, in the place of candles. Such resinous plants, observes Dr. Macculloch, as fir, would produce a fatter coal than oak, because the resin itself is converted into bitumen *.

Recent origin of some peat-mosses.—In Hatfield-moss, which appears clearly to have been a forest eighteen hundred years ago, fir-trees have been found ninety feet long, and sold for masts and keels of ships; oaks have also been discovered there above one hundred feet long. The dimensions of an oak from this moss are given in the Philosophical Transactions, No. 275,

* Syst. of Geol., vol. ii. p. 356.

which must have been larger than any tree now existing in the British dominions.

In the same moss of Hatfield, as well as in that of Kincardine and several others, Roman roads have been found covered to the depth of eight feet by peat. All the coins, axes, arms, and other utensils found in British and French mosses, are also Roman; so that a considerable portion of the European peat-bogs are evidently not more ancient than the age of Julius Cæsar. Nor can any vestiges of the ancient forests described by that general, along the line of the great Roman way in Britain, be discovered, except in the ruined trunks of trees in peat.

De Luc ascertained that the very site of the aboriginal forests of Hircinia, Semana, Ardennes, and several others, are now occupied by mosses and fens; and a great part of these changes have, with much probability, been attributed to the strict orders given by Severus, and other emperors, to destroy all the wood in the conquered provinces. Several of the British forests, however, which are now mosses, were cut at different periods by order of the English parliament, because they harboured wolves or outlaws. Thus the Welsh woods were cut and burnt in the reign of Edward I.; as were many of those in Ireland by Henry II., to prevent the natives from harbouring in them and harassing his troops.

It is curious to reflect, that considerable tracts have by these accidents been permanently sterilized, and that during a period when civilization has been making great progress, large areas in Europe have, by human agency, been rendered less capable of administering to the wants of man. Rennie observes with truth, that in those regions alone which the Roman eagle never reached—in the remote circles of the German empire, in Poland and Prussia, and still more in Norway, Sweden, and the vast empire of Russia—can we see what Europe was before it yielded to the power of Rome *. Desolation now reigns where stately forests of pine and oak once flourished,

* Essays, &c., p. 74.

such as might now have supplied all the navies of Europe with timber.

Sources of Bog Iron-ore.—At the bottom of peat-mosses there is sometimes found a cake, or 'pan,' as it is termed, of oxide of iron, and the frequency of bog iron-ore is familiar to the mineralogist. The oak which is so often found dyed black in peat, owes its colour to the same metal. From what source the iron is derived is by no means obvious, since we cannot in all cases suppose that it has been precipitated from the waters of mineral springs. According to Fourcroy there is iron in all compact wood, and it is the cause of one-twelfth part of the weight of oak. The heaths (*Ericæ*) which flourish in a sandy, ferruginous soil, are said to contain more iron than any other vegetable.

It has been suggested that iron, being soluble in acids, may be diffused through the whole mass of vegetables, when they decay in a bog, and may, by its superior specific gravity, sink to the bottom, and be there precipitated, so as to form bog iron-ore; or where there is a subsoil of sand or gravel, it may cement them into ironstone or ferruginous conglomerate *.

Preservation of animal substances in Peat.—One interesting circumstance attending the history of peat-mosses is the high state of preservation of animal substances buried in them for periods of many years. In June, 1747, the body of a woman was found six feet deep, in a peat-moor in the Isle of Axholm, in Lincolnshire. The antique sandals on her feet afforded evidence of her having been buried there for many ages; yet her nails, hair, and skin, are described as having shown hardly any marks of decay. In a turbary on the estate of the Earl of Moira, in Ireland, a human body was dug up, a foot deep in gravel, covered with eleven feet of moss; the body was completely clothed, and the garments seemed all to be made of hair. Before the use of wool was known in that country, the clothing of the inhabitants was made of hair, so that it would appear that this body had been buried at that early period; yet it was

* Dr. Rennie, Essays, &c., p. 347.

fresh and unimpaired *. In the Philosophical Transactions, we find an example recorded of the bodies of two persons having been buried in moist peat, in Derbyshire, in 1674, about a yard deep, which were examined twenty-eight years and nine months afterwards; 'the colour of their skin was fair and natural, their flesh soft as that of persons newly dead †.'

Among other analogous facts we may mention, that in digging a pit for a well near Dulverton, in Somersetshire, many pigs were found in various postures, still entire. Their shape was well preserved, the skin, which retained the hair, having assumed a dry, membranous appearance. Their whole substance was converted into a white, friable, laminated, inodorous, and tasteless substance; but which, when exposed to heat, emitted an odour precisely similar to broiled bacon ‡.

Cause of the antiseptic property of Peat.—We naturally ask whence peat derives this antiseptic property? It has been attributed by some to the carbonic and gallic acids which issue from decayed wood, as also to the presence of charred wood in the lowest strata of many peat-mosses, for charcoal is a powerful antiseptic, and capable of purifying water already putrid. Vegetable gums and resins also may operate in the same way §.

The tannin occasionally present in peat is the produce, says Dr. Macculloch, of tormentilla, and some other plants, but the quantity he thinks too small, and its occurrence too casual, to give rise to effects of any importance. He hints that the soft parts of animal bodies, preserved in peat-bogs, may have been converted into adipocire by the action of water merely; an explanation which appears clearly applicable to some of the cases above enumerated ||.

Miring of quadrupeds.—The manner, however, in which peat contributes to preserve, for indefinite periods, the harder parts of terrestrial animals, is a subject of more immediate

* Dr. Rennie, Essays, &c., p. 521, where several other instances are referred to.

† Phil. Trans., vol. xxxviii., 1734.

‡ Dr. Rennie, Essays, &c., p. 521.

§ Ibid., p. 531.

|| Syst. of Geol., vol. ii. p. 340—346.

interest to the geologist. There are two ways in which animals become occasionally buried in the peat of marshy grounds; they either sink down into the semifluid mud, underlying a turfy surface, upon which they have rashly ventured, or, at other times, a bog 'bursts,' in the manner described in a preceding chapter, and animals may be involved in the peaty alluvium.

In the extensive bogs of Newfoundland, cattle are sometimes found buried with their heads only and neck above ground, and after having remained for days in this situation, they have been drawn out by ropes and saved. In Scotland, also, cattle venturing on the 'quaking moss' are often mired, or 'laired,' as it is termed; and in Ireland, Mr. King asserts that the number of cattle which are lost in sloughs is quite incredible *.

Solway Moss.—The description given of the Solway moss will serve to illustrate the general character of these boggy grounds. That moss, observes Gilpin, is a flat area, about seven miles in circumference, situated on the confines of England and Scotland. Its surface is covered with grass and rushes, presenting a dry crust and a fair appearance; but it shakes under the least pressure, the bottom being unsound and semifluid. The adventurous passenger, therefore, who sometimes in dry seasons, traverses this perilous waste, to save a few miles, picks his cautious way over the rushy tussocks as they appear before him, for here the soil is firmest. If his foot slip, or if he venture to desert this mark of security, it is possible he may never more be heard of.

'At the battle of Solway, in the time of Henry VIII. (1542), when the Scotch army, commanded by Oliver Sinclair, was routed, an unfortunate troop of horse, driven by their fears, plunged into this morass, which instantly closed upon them. The tale was traditional, but it is now authenticated; a man and horse, in complete armour, having been found by peat-diggers, in the place where it was always supposed the affair

* Phil. Trans., vol. xv. p. 949.

had happened. The skeleton of each was well preserved, and the different parts of the armour easily distinguished *.'

This same moss, on the 16th of December, 1772, having been filled with water during heavy rains, rose to an unusual height and then burst. A stream of black half-consolidated mud began at first to creep over the plain, resembling, in the rate of its progress, an ordinary lava-current. No lives were lost, but the deluge totally overwhelmed some cottages, and covered 400 acres. The highest parts of the original moss subsided to the depth of about twenty-five feet, and the height of the moss, on the lowest parts of the country which it invaded, was at least fifteen feet.

Bursting of a peat-moss in Ireland.—A recent inundation in Sligo (January, 1831) affords another example of this phenomenon. After a sudden thaw of snow the bog between Bloomfield and Geevah gave way, and a black deluge, carrying with it the contents of a hundred acres of bog, took the direction of a small stream, and rolled on with the violence of a torrent, sweeping along heath, timber, mud, and stones, and overwhelming many meadows and arable land. On passing through some boggy land, the flood swept out a wide and deep ravine, and part of the road leading from Bloomfield to St. James's Well was completely carried away from below the foundation for the breadth of 200 yards.

Bones of herbivorous quadrupeds in peat.—The antlers of large and full-grown stags are amongst the most common and conspicuous remains of animals in peat. They are not horns which have been shed, for portions of the skull are found attached, proving that the whole animal perished. Bones of the ox, hog, horse, sheep, and other herbivorous animals, also occur; and in Ireland and the Isle of Man, skeletons of a gigantic elk; but no remains have been met with belonging to those extinct quadrupeds of which the living congeners inhabit warmer latitudes, such as the elephant, rhinoceros, hippopota-

* Observations on Picturesque Beauty, &c., 1772.

mus, hyæna, and tiger, though these are so common in superficial deposits of silt, mud, sand, or stalactite, in various localities throughout Great Britain. Their absence seems to imply that they had ceased to live before the atmosphere of this part of the world acquired that cold and humid character which favours the growth of peat.

Remains of ships, &c., in peat-mosses.—From the facts before mentioned, that mosses occasionally burst, and descend in a fluid state to lower levels, it will readily be seen that lakes and arms of the sea may occasionally become the receptacles of drift-peat. Of this, accordingly, there are numerous examples, and hence the alternations of clay and sand with different deposits of peat so frequent on some coasts, as on those of the Baltic and German Ocean. We are informed by Deguer that remains of ships, nautical instruments, and oars, have been found in many of the Dutch mosses; and Gerard, in his History of the Valley of the Somme, mentions that in the lowest tier of that moss was found a boat loaded with bricks, proving that these mosses were at one period navigable lakes and arms of the sea, as were also many mosses on the coast of Picardy, Zealand, and Friesland, from which soda and salt are procured *. The canoes, stone hatchets, and stone arrowheads, found in peat in different parts of Great Britain, lead to similar conclusions,—but these will more properly be considered when we treat of subaqueous phenomena.

Imbedding of Animal Remains in the Stalactite and Mud of Caves and Fissures.

We explained in the former volume how vast fissures have been formed from time to time by earthquakes, and suggested that the continual percolation of acidulous waters through rocks of limestone might have enlarged these fissures into caverns. We shall now consider in what manner the remains of animals may become preserved in rents and cavities, confining ourselves at present to the monuments of events which

* Dr. Rennie, Essays on Peat Moss, p. 205.

are known or can be inferred to have happened within the human era.

As the same caves and fissures may remain open throughout periods of indefinite duration, and may become the receptacles of the remains of species inhabiting a country at very different epochs, it requires the utmost care to avoid confounding together the monuments of occurrences of very distinct dates. Dr. Buckland, in his indefatigable researches into this class of phenomena, has often guarded with great skill against such anachronisms, pointing out the comparatively recent preservation of some organic relics which have become mingled in a common tomb with those of older date.

Fissures in calcareous rocks.—Fissures are very common in calcareous rocks, and these are usually, in the course of ages, filled up in part by small angular fragments of limestone, which scale off under the influence of frost and rain. Vegetable earth and land-shells are washed in at the same time, and the whole mass often becomes cemented together by calcareous matter dissolved by rain-water, or supplied by mineral springs. In an uncultivated country the edges of such fissures are usually overgrown with bushes, so that herbivorous animals, especially when chased by beasts of prey, or when carelessly browzing on the shrubs, are liable to fall in and perish. Of this kind is a fissure still open in Duncombe Park, in Yorkshire, where the skeletons of dogs, sheep, goats, deer, and hogs, have been found, lodged upon different ledges that occur at various depths in a rent of the rock descending obliquely downwards *.

Above the village of Selside, near Ingleborough in Yorkshire, a chasm of enormous but unknown depth occurs in the scar-limestone, a member of the carboniferous series. 'The chasm,' says Professor Sedgwick, 'is surrounded by grassy shelving banks, and many animals, tempted towards its brink, have fallen down and perished in it. The approach of cattle is now prevented by a strong lofty wall, but there can be no

* Buckland, Reliquiæ Diluvianæ, p. 55.

doubt that, during the last two or three thousand years, great masses of bony breccia must have accumulated in the lower parts of the great fissure, which probably descends through the whole thickness of the scar-limestone, to the depth of perhaps five or six hundred feet *.'

Formation of breccias.—A fissure in the limestone of the Coiron, in France, is seen on the high road between Aubenas and Ville-Dieu, filled with a breccia, consisting of angular fragments of the rock and land-shells cemented together. The mode of its formation is admirably illustrated by the rapid growth of a similar deposit not far distant. At the pass of Escrinet, on the northern escarpment of the Coiron hills, near Aubenas, a tabular mass of limestone is seen disintegrating into innumerable angular fragments, which are transported by the rain to the foot of the declivity, where they have accumulated at one spot, in a talus fifty feet in thickness and five hundred yards wide. The upper part is composed for the most part of loose fragments, on which numerous land-shells are seen living; the lower portion is consolidated by stalagmite into a compact mass which serves for mill-stones. The calcareous cement has a red tinge, but not of so deep a colour as most of the Mediterranean breccias †.

By the decomposition of the calcareous rocks near Nice, a soil is produced of a blood-red colour; and red breccias, consisting of fragments of rock and land-shells cemented together, are continually forming. If the mountains here were rent by earthquakes, we might expect the fissures to be gradually filled with red breccias like those of higher antiquity so celebrated in many parts of the Mediterranean.

Preservation of organic remains in caves.—It often happens that fissures communicate with subterranean caverns, a fact somewhat confirmatory of the views of those geologists who attribute the origin of limestone caverns in great part to the

* Memoir on the Structure of the Lake Mountains of the North of England, &c., read before the Geological Society, January 5, 1831.

† I examined this spot in the year 1828, accompanied by Mr. Murchison.

movements and dislocations of the strata. In this case the fissure may serve for ages as a natural pit-fall to animals passing by, and their bones, with all the earth, sand, and fragments of rock that fall through these passages, may be washed down or subside by their own weight, so as to reach the cavern below where thick deposits may be amassed.

Oftentimes when the bones of animals are strewed along the bottom of fissures or caves which they may have inhabited, they become covered over with mud introduced by land-floods, and are thus preserved from decomposition. Thus on the floor of many caverns mentioned by Dr. Buckland, in the Mendip hills and Derbyshire, sedimentary mud has been left in recent times during floods.

Alternations of stalagmite and alluvium.—The same author observed in every cave examined by him in Germany, a deposit of mud or sand, sometimes with, and sometimes without, an intermixture of rolled pebbles and angular fragments of rock, and having its surface covered over with a *single* crust of stalagmite *. In the English caves he remarked a similar absence of *alternations* of alluvium and stalagmite. On the banks of the Meuse, however, at Chockier, about two leagues from Liège, a cavern has been recently discovered where there are three distinct beds of stalagmite, between each of which occur breccia and mud, mixed with some quartz pebbles, and the bones of extinct quadrupeds †.

But this exception does not invalidate the generality of the phenomenon observed by the Professor, and of which we have as yet seen no satisfactory explanation. The principal cause we suspect to be, that if several floods pass at different intervals of time through any subterranean passage, the last, if it has power to drift along fragments of rock, will also tear up any alternating stalagmitic and alluvial beds that may happen to have been previously formed. Another cause may be, that in a country in which torrents and rivers are gradually deepening

* Rel. Dil., p. 108.

† Journ. de Géologie, tome i. p. 286. July, 1830.

their channels, and cutting through masses of cavernous limestone (an excavating process which is most rapid during epochs of subterranean disturbance, when the levels of a district are altered), it will only happen once that the stream will break into hollows or fissures communicating with a certain series of caverns. When the erosive action has proceeded farther, and the river has sunk to a greater depth, the drainage of the country will be effected in a valley at a level inferior to that of the caves, and consequently no transported matter will afterwards be introduced into them.

In the cave of Paviland, called Goat's Hole, on the coast of Glamorganshire, besides the bones of many extinct animals which occur in a mass of loam, a modern breccia has been formed, consisting of earth cemented by stalagmite, and containing marine-shells and birds' bones, all of recent species. The mouth of this cave is from thirty to forty feet above high-water mark, being situated in a lofty cliff of limestone, facing the estuary of the Severn, the waves of which, during great storms, occasionally dash into it. The left side of a human skeleton was also found here under a cover of six inches of earth. In a cavernous aperture leading from the roof of this cave to the face of the cliff was discovered a bed of brown earth, apparently derived from dust driven in continually by the wind; and in this earth were the bones of various birds, of moles, water rats, mice, and fish, and a few land-shells, all clearly the remains of modern animals. Their presence in this almost inaccessible spot can only be explained, says Dr. Buckland, 'by referring the bones of birds, moles, rats, and mice, to the agency of hawks, and the fish-bones to that of sea-gulls. The land-shells, which are such as live at present on the rock without, may easily have fallen in. Had there been any stalagmite uniting these bones into a breccia, they would have afforded a perfect analogy to the accumulation of modern birds' bones, by the agency of hawks, at Gibraltar *.'

The formation last alluded to occurs in perpendicular fis-

* Buckland, Reliquiæ Diluvianæ, p. 93.

sures at the north extremity of the rock of Gibraltar, where a reddish calcareous earth, containing numerous bones of small birds, is in the act of accumulating. Around these fissures a number of hawks nestle and rear their young in the breeding-season, and the bones are the remains of their food. Major Imrie mentions also a concretion in the rocks below King's Lines, Gibraltar, consisting of pebbles of the prevailing calcareous rock, wherein, at a considerable depth under the surface, part of a green glass bottle was found imbedded *.

In a cave of mountain-limestone at Burringdon, in the Mendip hills, supposed to have been once used as a place of sepulture or refuge, human bones have been met with, encrusted with stalactite, one of the skulls being filled with this substance in the interior †. The state of the bones, says Dr. Buckland, affords indications of very high antiquity.

The remains of human skeletons have been also found in the cave of Wokey Hole, near Wells, in the Mendips, dispersed through reddish mud and clay, and some of them united by stalagmite into a firm osseous breccia. 'The spot on which they lie is within reach of the highest floods of the adjacent river, and the mud in which they are buried is evidently fluviatile ‡.'

Bones of man and extinct quadrupeds intermixed.—We shall conclude with alluding to some caverns recently examined in the south of France, in which human bones and fragments of pottery are described as intermingled in the same deposits with the remains of extinct mammalia. We may first mention the cavern of Bize, in the department of Aude, where M. Marcel de Serres met with a small number of human bones mixed with those of extinct animals and with land-shells. They occur in a calcareous stony mass, bound together by a cement of stalagmite. On examining the same caverns, M. Tournal found not only in these calcareous beds, but also in a black mud which overlies a red osseous mud, several human

* Buckland, Reliquiæ Diluvianæ, p. 156.

† Ibid., p. 164. ‡ Ibid., p. 165.

teeth, together with broken angular fragments of a rude kind of pottery, and also marine and terrestrial shells of our own epoch. The teeth preserve their enamel, but the fangs are so much altered as to adhere strongly when applied to the tongue. Of the terrestrial shells thus associated with the bones and pottery, the most common are Cyclostoma elegans, Bulimus decollatus, Helix nemoralis and H. nitida. Among the marine are found Pecten jacobæus, Mytilus edulis, and Natica mille-punctata, all of them eatable kinds. Bones of quadrupeds were found in the same mass belonging to three new species of the deer kind, an extinct bear (*Ursus arctoïdeus*), besides the wild bull (*Bos urus*), formerly a native of Germany *.

In the same part of France, M. de Christol has found in caverns in a tertiary limestone at Pondres and Souvignargues, situated two leagues north of Lunel-viel, (department of Herault,) human bones and pottery confusedly mixed with the remains of the rhinoceros, bear, hyæna, and many other terrestrial mammifers. They were imbedded in an alluvial mud, of the solidity of calcareous tufa, and containing some flint pebbles and fragments of the limestone of the country. Beneath this mixed accumulation, which sometimes attained a thickness of thirteen feet, is the original floor of the cavern, about a foot thick, covered with bones and the dung of animals (*album græcum*), in a sandy and tufaceous cement.

The human bones in these caverns of Pondres and Souvignargues were found, upon a careful analysis, to have parted with their animal matter to as great a degree as those of the hyæna which accompany them, and are equally brittle, and adhere as strongly to the tongue.

In order to compare the degree of alteration of these bones with those known to be of high antiquity, M. Marcel de Serres, and M. Ballard, Chemist of Montpellier, procured some from a Gaulish sarcophagus in the plain of Lunel, supposed to have been buried for fourteen or fifteen centuries at least. In these the cellular tissue was empty, but they were

* M. Marcel de Serres, Géognosie des Terrains Tertiaires, p. 64. Introduction.

more solid than fresh bones. They did not adhere to the tongue in the same manner as those of the caverns of Bize and Pondres, yet they had lost at least three-fourths of their original animal matter.

The superior solidity of the Gaulish bones to those in a fresh skeleton is a fact in perfect accordance with the observations made by Mr. Mantell on bones taken from a Saxon tumulus near Lewes.

Inferences deducible from such associations.—Let us now consider what conclusions are deducible from the important facts above enumerated. Must we infer that man and these extinct quadrupeds were contemporaneous inhabitants of the south of France at some former epoch? We should unquestionably have arrived at this conclusion if the bones had been found in an undisturbed *stratified* deposit of subaqueous origin, especially if it contained shells in regular layers like that of North-Cliff in Yorkshire, described by Mr. Vernon, from which we learn that the mammoth coexisted with thirteen species of our living British land and fresh-water testacea*. But we must hesitate before we draw analogous inferences from evidences so equivocal as that afforded by the mud, stalagmites and breccias of caves, where the signs of *successive* deposition are wanting.

No one will maintain that man, the hyæna, and the bear, were at once joint tenants of these caverns; and if it be necessary to assume that the mud and pebbles were washed into their present position by floods, the same inundations might possibly have caught up the bones lying in more ancient deposits, and thus have mingled the whole together in the same mass.

More than ordinary caution is required in reasoning on the occurrence of human remains and works of art in alluvial deposits, since the chances of error are much greater than when we have the fossil bones of the inferior animals only under consideration. For the floor of caves has usually been dis-

* See ante, vol. i. chap. vi.

turbed by the aboriginal inhabitants of each country, who have used such retreats for dwelling places, or for concealment, or sepulture. In such spots have treasures been often buried in periods of disturbance, or diligently sought for in times of tranquillity. The excavations made in Sicily for treasure-trove, in places where no money was ever buried, are believed to exceed in number all the spots in which coin was ever hid during the wars between the Saracens and Christians.

Dr. Buckland, in speaking of the cave of Paviland, before mentioned, states that the entire mass through which the bones were dispersed, appeared to have been disturbed by ancient diggings, so that the remains of extinct animals had, in that instance, actually become mixed with the recent bones and shells. In the same cave he found a human skeleton, and the remains of recent testacea of eatable species, which may have been carried in by man. The same observation is applicable to the marine testacea of the cavern of Bize, and we suspect the whole phenomena to be very analogous.

To decide whether certain relics have been introduced by man, or natural causes, into masses of transported materials, must almost always be a task of some difficulty, especially where all the substances, organic and inorganic, have been mixed together and consolidated into one breccia; a change soon effected by the percolation of water charged with carbonate of lime. It is not on such evidence that we shall readily be induced to admit either the high antiquity of the human race or the recent date of certain lost species of quadrupeds.

CHAPTER XIV.

Imbedding of organic remains in alluvium and the ruins caused by landslips—Effects of sudden inundations—Of landslips—Terrestrial animals most abundantly preserved in alluvium and landslips, where earthquakes prevail—Erroneous theories which may arise from overlooking this circumstance—On the remains of works of art included in alluvial deposits—Imbedding of organic bodies and human remains in blown sand—Temple of Ipsambul on the Nile—Dried carcasses of animals buried in the sands of the African deserts—Towns overwhelmed by sand-floods in England and France—Imbedding of organic bodies and works of art in volcanic formations on the land—Cities and their inhabitants buried by showers of ejected matter—by lava—In tuffs or mud composed of volcanic sand and ashes.

In continuing our investigation of the manner in which the animal and vegetable creation leave permanent marks of their existence on the *emerged* lands we have next to examine,

The imbedding of organic remains in alluvium, and the ruins caused by landslips.

We restrict the term *alluvium* to such transported matter as has been thrown down, whether by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas.

River alluvium.—The alluvium of the bed of a river does not often contain any animal or vegetable remains, for the whole mass is so continually shifting its place, and the attrition of the various parts is so great, that even the hardest rocks contained in it are, at length, ground down to powder. But when sand, mud, and rubbish, are suddenly swept by a flood, and then let fall upon the land, such an alluvium may envelop trees or the remains of animals, which may, in this manner, be permanently preserved.

Effects of sudden floods.—The sudden descent of a body of water which had been discharged by a small artificial drain

from a lake in Vermont, in the United States, in 1810, covered a wide valley with the spoils of the land washed down from the higher country. Deep accumulations of mud and sand were spread far and wide, and, in some places, deposits of timber were heaped up, from twenty to eighty feet in height *.

Effects of landslips.—Analogous results happen, from time to time, when the course of a river has been obstructed by landslips, volcanic ejections, masses of ice, or other impediments, and when the waters of temporary lakes so caused burst through the barrier. Besides these indirect effects, the landslip, by suddenly precipitating large masses of rock and soil into a valley, overwhelms a multitude of animals, and sometimes buries permanently whole villages, with their inhabitants and large herds of cattle. Thus three villages, with their entire population, were covered, when the mountain of Piz fell in 1772, in the district of Treviso, in the state of Venice †; and part of Mount Grenier, south of Chambery, in Savoy, which fell down in the year 1248, buried five parishes, including the town and church of St. André, the ruins occupying an extent of about nine square miles ‡.

The number of lives lost by the slide of the Rossberg, in Switzerland, in 1806, was estimated at more than 800, a great number of the bodies being buried under mud and rock, at great depths, as well as several villages and scattered houses. In the same country, several hundred cottages, with eighteen of their inhabitants and a great number of cows, goats, and sheep, were victims to the sudden fall of a bed of stones, thirty yards deep, which descended from the summits of the Diablerets. In the year 1618, a portion of Mount Conto fell, in the county of Chiavenna in Switzerland, and buried the town of Pleurs with all its inhabitants, to the number of 2430.

Terrestrial animals most abundantly preserved where earthquakes prevail.—It is unnecessary to multiply examples of similar local catastrophes, which, however numerous they may

* Ed. New Phil. Journ., No. III. 146.

† Malte-Brun's Geog., vol. i. 435.

‡ Bakewell, Travels in the Tarentaise, vol. i. p. 201.

have been in the mountainous parts of Europe, within the historical period, have been, nevertheless, of rare occurrence in comparison to the events of the same kind which take place in regions convulsed by earthquakes. It is then that all the causes whereby terrestrial animals may be buried in superficial alluvium are in full activity; in proof of which we need only refer the reader to our description, in the former volume, of the effects of great subterranean movements in disturbing the drainage of a country and altering its levels. When the shocks are violent, enormous masses of rock and earth, even in comparatively low and level countries, are detached from the sides of valleys, and cast down into the river-courses. The slides are so rapid and unexpected, that they often overwhelm, in the day-time, every living thing upon the plain; and when they happen in the night, escape is impossible. Although the streams are often only partially dammed up by the ruins thrown into their channel, the waters, nevertheless, collect in sufficient quantity to form torrents of mud, which, as we have seen in Calabria, sometimes bear along uprooted trees, and overwhelm animals, until, wherever they cease to move, the mass shrinks on drying, and becomes hard and compact *.

Erroneous theories which may arise from overlooking this circumstance.—Many geologists, who seem desirous of ascribing as little power as possible to the aqueous causes now acting, are in the habit of overlooking the effects which the force of running water can produce, when combined with the movements of ordinary earthquakes. In a country like Great Britain, where the height of mountain-chains is not considerable, and where the shocks of earthquakes are rare and extremely feeble, scarcely any remains of terrestrial animals or plants are buried in alluvial deposits, in such a manner as to lead us to expect that they will be preserved for indefinite periods. Some skeletons, it is true, are occasionally imbedded, as, for example, in the mud and sand produced by the floods

* Vol. i. chap. xxiv.

in Scotland, in 1829, in which the dead and mutilated bodies of hares, rabbits, moles, mice, partridges, and even the bodies of men, were found drifted and partially buried *. But if the levels of a country remain unchanged, one flood usually effaces the memorials left by another, and there is rarely a sufficient depth of undisturbed transported matter in any one spot, to preserve the organic remains permanently from destruction.

The catastrophes, on the other hand, which arise from repeated earthquakes, cause not only the death of many animals, but their frequent inhumation in alluvium, so placed as to escape degradation for a succession of ages. When a valley has been half choked up with mud, sand, and gravel, or when numerous slides from the boundary hills have encumbered it with ruin, a river takes a new direction, finding, perhaps, its way through a new-formed fissure. From that moment the transported matter is no longer exposed to be undermined and removed by the action of running water.

Portions, also, of plains loaded with alluvial accumulations by transient floods, may be gradually upraised by earthquakes; and, if any organic remains have been imbedded in the transported materials, they will, after such elevation, remain undisturbed, and beyond the reach of the erosive power of streams. Every fissure, every hollow caused by the sinking in of land, becomes a receptacle of organic and inorganic substances, hurried along by transient floods, in districts where the drainage is repeatedly deranged by subterranean movements.

We have seen that the ravines which opened in Calabria, in 1783, were very numerous, varying in depth from fifty to two hundred feet †; and that animals were sometimes engulphed during the shocks. We may assume that many others fell in during the three years that the earthquakes continued, and that similar casualties happen in the intervals between convulsions. Every inundation, therefore, caused by

* Sir T. D. Lauder, Bart., on the great floods in Morayshire, August, 1829, p. 177.

† Vol. i. chap. xxiv.

heavy rains, every torrent that might chance to be in the line of any of these chasms, would pour in a quantity of mud, sand, and rolled pebbles, together with fragments of the adjacent rocks, and under these the animal remains might lie inhumed for ages.

Where houses with their inhabitants have been swallowed up in fissures, there appears to have been usually a sliding in of all the loose matter which lay upon the surface, so that, in such rents, we might look for rolled pebbles, mud, sand, angular fragments of rocks, ruins of buildings, and skeletons of men and animals, at the depth often of several hundreds of feet. It is obvious that a suite of subterranean caverns, communicating with such fissures, might become wholly or partially filled with these various materials confusedly mixed together.

During the great earthquake of 1693, in Sicily, several thousand people were at once entombed in the ruins of caverns in limestone, at Sortino Vecchio; and, at the same time, a large stream, which had issued for ages from one of the grottos below that town, changed suddenly its subterranean course, and came out from the mouth of a cave lower down the valley, where no water had previously flowed. To this new point the ancient mills were transferred.

When the courses of engulphed rivers are thus liable to change, from time to time, by alterations in the levels of a country, and by the rending and shattering of mountain masses, we must suppose that the dens of wild beasts will sometimes be inundated by subterranean floods, and their carcasses buried under heaps of alluvium. The bones, moreover, of individuals which have died in the recesses of caves, or of animals which have been carried in for prey, may be drifted along, and mixed up with mud, sand, and fragments of rock, so as to form osseous breccias.

Nor should we omit to mention the havoc committed on low coasts, during earthquakes, by waves of the sea which roll in upon the land, bearing everything before them, for many miles

into the interior, throwing down upon the surface great heaps of sand and rock, by which the remains of drowned animals may be overwhelmed. Many of the storms termed hurricanes have evidently been connected with submarine earthquakes, as is shown by the atmospheric phenomena attendant on them, and by the sounds heard in the ground, and the odours emitted. Such were the circumstances which accompanied the swell of the sea in Jamaica, in 1780, when a great wave desolated the western coast, and, bursting upon Savanna la Mar, swept away the whole town in an instant, so that not a vestige of man, beast, or habitation, was seen upon the surface *.

Now let us suppose that in a tract of land constantly inhabited by terrestrial quadrupeds, the species are thrice changed under the gradual influence of causes before considered in this volume, and that, during the first and last of the zoological epochs, the district remains entirely free from earthquakes, but is violently convulsed by them during the intermediate era,—we should expect, for reasons above considered, that the fossil remains of quadrupeds, buried in alluvium, would be confined to one period only, viz., that of the subterranean movements. If the series of shocks should happen not to have occupied the whole of the second epoch, but only a small portion of it, there might be no indication whatever, in the fossil relics, of a passage from one state of the organic world to another. The transition would appear abrupt; and they who, for the sake of economizing past time, do not hesitate to magnify the energies of natural agents in by-gone ages, might then imagine one paroxysmal earthquake to have caused all the fissures, caverns, and depressions, and one accompanying deluge to have filled the whole with alluvial matter, annihilating, at the same time, the race of quadrupeds of which the bones remain interred.

Works of art in alluvial deposits.—But although we conceive that, in a country entirely free from subterranean movements, a long succession of ages might pass away without any

* Edwards, Hist. of West Indies, vol. i. p. 235, Ed. 1801.

permanent monuments being left in *alluvium* of the terrestrial animals which have lived upon the surface, yet it appears scarcely possible that man, if he has made considerable progress in civilization, should fail to leave some lasting signs of the works of his hands, to testify his former existence. We are informed by M. Boblaye, that in the Morea, the formation termed céramique, consisting of pottery, tiles, and bricks, intermixed with various works of art, enters so largely into the alluvium and vegetable soil upon the plains of Greece, and into hard and crystalline breccias which have been formed at the foot of declivities, that it constitutes a real stratum which might, in the absence of zoological characters, serve to mark our epoch in a most indestructible manner *.

Imbedding of Human and other Remains and Works of Art in Blown Sand.

Temple of Ipsambul.—The drifting of sand is the next cause which we may consider among those capable of preserving the remains of the inhabitants of the land during its period of emersion. We have already alluded to the African deserts, as the most remarkable example of desolation produced by this cause. Innumerable towns and cities have been buried to the westward of the Nile, between the temple of Jupiter Ammon and Nubia; and it is scarcely possible to conceive a mode whereby interment could take place under circumstances more favourable to the conservation of monuments for indefinite periods. The sand which surrounded and filled the great temple of Ipsambul, first discovered by Burckhardt, and afterwards partially uncovered by Belzoni and Beechey, was so fine as to resemble a fluid when put in motion. Neither the features of the colossal figures, nor the colour of the stucco with which some were covered, nor the paintings on the walls, had received any injury from being enveloped for ages in this dry impalpable dust †.

* Ann. des Sci. Nat., tome xxii. p. 117. Feb. 1831.

† Stratton, Ed. Phil. Journ., No. V. p. 62.

At some future period, perhaps, when the pyramids shall have perished, the action of the sea, or an earthquake, may lay open to the day some of these buried temples. Or we may suppose the desert to remain undisturbed, and changes in the surrounding sea and land to modify the climate and the direction of the prevailing winds, so that these may then waft away the Lybian sands as gradually as they once brought them to those regions. Thus many a town and temple of higher antiquity than Thebes or Memphis might reappear in their original integrity, and a part of the gloom which overhangs the history of earlier nations might be dispelled.

Dried carcasses on African sands.—Whole caravans are said to have been overwhelmed by the Lybian sands; and Burckhardt informs us that 'after passing the Akaba, near the head of the Red Sea, the bones of dead camels are the only guides of the pilgrim through the wastes of sand.' 'We did not see,' says Captain Lyon, speaking of a plain near the Soudah mountains, in Northern Africa, 'the least appearance of vegetation; but observed many skeletons of animals, which had died of fatigue on the desert, and occasionally the grave of some human being. All these bodies were so dried by the heat of the sun, that putrefaction appears not to have taken place after death. In recently-expired animals I could not perceive the slightest offensive smell; and in those long dead the skin with the hair on it remained unbroken and perfect, although so brittle as to break with a slight blow. The sand-winds never cause these carcasses to change their places, for in a short time a slight mound is formed round them, and they become stationary *.'

Towns overwhelmed by sand-floods.—The burying of several towns and villages in England and France by blown sand is on record; thus, for example, in Suffolk, in the year 1688, part of Downham was overwhelmed by sands which had broken loose about one hundred years before, from a warren five miles to the south-west. This sand had, in the course of a century,

* Travels in North Africa in the years 1818, 1819, and 1820, p. 83.

travelled five miles, and covered more than a thousand acres of land *.

The ruins of buildings have been found entire in the drift-sand of Cornwall, as we before mentioned, as also land-shells. One of the latter is said to belong to a species which is unknown at present in this country †. Near St. Pol de Leon, in Brittany, a whole village was completely buried beneath drift-sand, so that nothing was seen but the spire of the church ‡.

Imbedding of Organic Bodies and Works of Art in Volcanic Formations on the Land.

We have in some degree anticipated the subject of this section in a former volume, when speaking of the buried cities around Naples, and those on the flanks of Etna §. From the facts referred to by us, it appears that the preservation of human remains and works of art has been frequently due to the descent of floods caused by the copious rains which usually accompany eruptions. These aqueous lavas, as they are called in Campania, flow with great rapidity, and in 1822 surprised and suffocated, as we have stated, seven persons in the villages of St. Sebastian and Massa, on the flanks of Vesuvius.

In the tuffs, moreover, or solidified mud, deposited by these aqueous lavas, impressions of leaves and of trees have been observed. Some of those formed after the eruption of Vesuvius in 1822, are now preserved in the museum at Naples.

Lava itself may become indirectly the means of preserving terrestrial remains, by overflowing beds of ashes, pumice, and ejected matter, which may have been showered down upon animals and plants, or upon human remains. Few substances are better non-conductors of heat than volcanic dust and scoriæ, so that a bed of such materials is rarely melted by a superimposed lava-current. After consolidation, the lava affords secure pro-

* Phil. Trans., vol. ii. p. 722. † Vol. i. chap. xvi.

‡ Mém. de l'Acad. des Sci. de Paris, 1772.—Malte-Brun's Geog. vol. i. p. 425.

§ Vol. i. chaps. xx. and xxi.

tection to the lighter and more removeable mass below, wherein the organic relics may be enveloped. The Herculanean tuffs containing the rolls of papyrus, of which the characters are still legible, have, as we before remarked, been for ages covered by lava.

Another mode whereby lava may tend to the conservation of imbedded remains, at least of works of human art, is by overflowing them when not intensely heated, in which case they often suffer little or no injury.

Thus when the Etnean lava-current of 1669 covered fourteen towns and villages, and part of the city of Catania, it did not melt down a great number of statues and other articles in the vaults of Catania; and at the depth of thirty-five feet in the same current, on the site of Mompiliere, one of the buried towns, the bell of a church and some statues were found uninjured *.

We remarked in a former volume, that in many countries which have been peopled from remote ages by civilized nations, and have been at the same time the theatres of volcanic action, there must be innumerable monuments of the highest value to the historian, which continue unobserved 'because they have not been searched for.' But we omitted to describe in detail a splendid example of several buried cities in Central India, which might probably be made to yield a richer harvest to the antiquary than Pompeii and Herculaneum †. The city of Oujein (or Oojain) was, about fifty years before the Christian era, the seat of empire, of art, and of learning; but in the time of the Rajah Vicramaditya, it was overwhelmed, together, as tradition reports, with more than eighty other large towns in the provinces of Malwa and Bagur, 'by a shower of earth.' The city which now bears the name is situated a mile to the southward of the ancient town. On digging on the spot where the latter is supposed to have stood, to the depth of fifteen or eighteen feet, there are frequently discovered, says Mr. Hunter, entire brick walls, pillars of stone, and pieces of wood of an

* Vol. i. chap. xxi. † Ibid., chap. xxiii.

extraordinary hardness, besides utensils of various kinds, and ancient coins. Many coins are also found in the channels cut by the periodical rains, or in the beds of torrents into which they have been washed. 'During our stay at Oujein, a large quantity of wheat was found by a man digging for bricks. It was, as might have been expected, almost entirely consumed, and in a state resembling charcoal. In a ravine cut by the rains, from which several stone pillars had been dug, I saw a space from twelve to fifteen feet long and seven or eight high, composed of earthen vessels, broken and closely compacted together. It was conjectured, with great appearance of probability, to have been a potter's kiln. Between this place and the new town is a hollow, in which, tradition says, the river Sipparah formerly ran. It changed its course at the time the city was buried, and now runs to the westward *.' The soil which covers Oujein is described as 'being of an ash-grey colour, with minute specks of black sand †.'

That the 'shower of earth' which is reported to have 'fallen from heaven,' was produced by a volcanic eruption, we cannot doubt, although no information has been obtained respecting the site of the vent; and the nearest volcano of which we read, is that which was in eruption during the Cutch earthquake in 1819, at the distance of about thirty miles from Bhooi, the capital of Cutch, and at least three hundred geographical miles from Oujein.

Captain F. Dangerfield, who accompanied Sir John Malcolm in his late expedition into Central India, states that the river Nerbuddah, in Malwa, has its channel excavated through *columnar basalt*, on which rest beds of marl impregnated with salt. The upper of these beds is of a light colour, and from thirty to forty feet thick, and rests horizontally on the lower bed, which is of a reddish colour. Both appear from the description to be tuffs composed of the materials of volcanic ejections, and forming a covering from sixty to seventy feet

* Narrative of Journey from Agra to Oujein, Asiatic Researches, vol. vi. p. 36.

† Asiatic Journal, vol. ix. p. 35.

deep overlying the basalt, which seems to resemble some of the currents of prismatic lava in Auvergne and the Vivarais. Near the middle of this tufaceous mass, and therefore at the depth of thirty feet or more from the surface, just where the two beds of tuff meet, Captain Dangerfield was shown, near the city of Mhysir, buried bricks and large earthen vessels, said to have belonged to the ancient city of Mhysir, destroyed by the catastrophe of Oujein *.

* Sir J. Malcolm's Cent. Ind.—Geol. of Malwa, by Captain F. Dangerfield, App. No. ii. pp. 324, 325.

CHAPTER XV.

Imbedding of organic remains in subaqueous deposits—Division of the subject—Phenomena relating to terrestrial animals and plants first considered—Wood sunk to a great depth in the sea instantly impregnated with salt-water—Experiments of Scoresby—Drift timber carried by the Mackenzie into Slave Lake and into the sea—Cause of the abundance of drift timber in this river—Floating trees in the Mississippi—In the Gulf stream—Immense quantity thrown upon the coast of Iceland, Spitzbergen, and Labrador—Imbedding of the remains of insects—of the remains of reptiles—Why the bones of birds are so rare in subaqueous deposits—Imbedding of terrestrial quadrupeds—Effects of a flood in the Solway Firth—Wild horses annually drowned in the savannahs of South America—Skeletons in recent shell marl—Drifting of mammiferous and other remains by tides and currents.

IMBEDDING OF ORGANIC REMAINS IN SUBAQUEOUS DEPOSITS.

Division of the subject.—We have treated hitherto of the imbedding of organic remains in deposits formed upon the emerged land, and we shall next consider the including of the same in deposits formed under water.

It will be convenient to divide this branch of our subject into three parts; considering, first, the various modes whereby the relics of *terrestrial* species may be buried in subaqueous formations; secondly, the modes whereby the animals and plants inhabiting *fresh-water* may be so entombed; thirdly, the manner in which *marine* species may become preserved in new strata.

The phenomena which we are now about to notice demand a fuller share of attention than those previously examined, since the deposits which originate upon the dry land are insignificant in thickness, superficial extent, and durability, when contrasted with those of subaqueous origin. At the same time, the study of the latter is beset with greater difficulties, for we are here concerned with the results of processes much more removed from the sphere of ordinary observation.

There is, indeed, no circumstance, as we before remarked *, which more seriously impedes the acquisition of just views in the etiology of our science, that an habitual disregard of the important fact, that the reproductive effects of the principal agents of change are confined to another element,—to that larger portion of the habitable globe, from which, by our very organization, we are almost entirely excluded.

Imbedding of Terrestrial Plants.

When a tree falls into a river from the undermining of the banks, or from being washed in by a torrent or flood, it floats on the surface, not because the woody portion is specifically lighter than water, but because it is full of pores containing air. When soaked for a considerable time, the water makes its way into these pores, and the wood becomes *water-logged* and sinks. The time required for this process varies differently in different woods, but several kinds may be drifted to great distances, sometimes across the ocean, before they lose their buoyancy.

Wood sunk to a great depth in the sea instantly impregnated with salt water.—If wood be sunk to vast depths in the sea, it may be impregnated with water suddenly. Captain Scoresby informs us, in his Account of the Arctic Regions *, that on one occasion a whale, on being harpooned, ran out all the lines in the boat, which it then dragged under water, to the depth of several thousand feet, the men having just time to escape to a piece of ice. When the fish returned to the surface 'to blow,' it was struck a second time, and soon afterwards killed. The moment it expired it began to sink,—an unusual circumstance, which was found to be caused by the weight of the sunken boat, which still remained attached to it. By means of harpoons and ropes the fish was prevented from sinking until it was released from the weight by connecting a rope to the lines of the attached boat, which was no sooner done than the fish rose again to the surface. The sunken boat was then

* Vol. i. chap. 5. † Vol. ii. p. 191.

hauled up with great labour, for so heavy was it, that although before the accident it would have been buoyant when full of water, yet it now required a boat at each end to keep it from sinking. 'When it was hoisted into the ship, the paint came off the wood in large sheets; and the planks, which were of wainscot, were as completely soaked in every pore, as if they had lain at the bottom of the sea since the flood! A wooden apparatus that accompanied the boat in its progress through the deep, consisting chiefly of a piece of thick deal, about fifteen inches square, happened to fall overboard, and, though it originally consisted of the lightest fir, sank in the water like a stone. The boat was rendered useless; even the wood of which it was built, on being offered to the cook for fuel, was tried and rejected as incombustible *.'

Captain Scoresby found that, by sinking pieces of fir, elm, ash, &c., to the depth of 4000 and sometimes 6000 feet, they became impregnated with sea-water, and when drawn up again, after immersion for an hour, would no longer float. The effect of this impregnation was to increase the dimensions as well as the specific gravity of the wood, every solid inch having increased one-twentieth in size and twenty-one twenty-fifths in weight †.

Drift-wood of the Mackenzie river.—When timber is drifted down by a river, it is often arrested by lakes, and, becoming water-logged, it may sink and be imbedded in lacustrine strata, if any be there forming: sometimes a portion floats on till it reaches the sea. In the course of the Mackenzie River we have an example of vast accumulations of vegetable matter now in progress under both these circumstances.

In Slave Lake in particular, which vies in dimensions with some of the great fresh-water seas of Canada, the quantity of drift-timber brought down annually is enormous. 'As the trees,' says Dr. Richardson, 'retain their roots, which are often loaded with earth and stones, they readily sink, especially when water-soaked, and, accumulating in the eddies,

* Account of the Arctic Regions, vol. ii. p. 193. † Ibid., p. 202.

form shoals, which ultimately augment into islands. A thicket of small willows covers the new-formed island as soon as it appears above water, and their fibrous roots serve to bind the whole firmly together. Sections of these islands are annually made by the river, assisted by the frost; and it is interesting to study the diversity of appearances they present, according to their different ages The trunks of the trees gradually decay until they are converted into a blackish brown substance resembling peat, but which still retains more or less of the fibrous structure of the wood; and layers of this often alternate with layers of clay and sand, the whole being penetrated, to the depth of four or five yards or more, by the long fibrous roots of the willows. A deposition of this kind, with the aid of a little infiltration of bituminous matter, would produce an excellent imitation of coal, with vegetable impressions of the willow-roots. What appeared most remarkable was the horizontal slaty structure that the older alluvial banks presented, or the *regular curve* that the strata assumed from unequal subsidence.

'It was in the rivers only that we could observe sections of these deposits, but the same operation goes on on a much more magnificent scale in the lakes. A shoal of many miles in extent is formed on the south side of Athabasca Lake, by the drift-timber and vegetable debris brought down by the Elk River; and the Slave Lake itself must in process of time be filled up by the matters daily conveyed into it from Slave-River. Vast quantities of drift timber are buried under the sand at the mouth of the river, and enormous piles of it are accumulated on the shores of every part of the lake *.'

The banks of the Mackenzie display almost everywhere horizontal beds of wood coal, alternating with bituminous clay, gravel, sand, and friable sandstone; sections, in short, of such deposits as are now evidently forming at the bottom of the lakes which it traverses.

Notwithstanding the vast forests intercepted by the lakes, a

* Dr. Richardson's Geognost. Obs. on Capt. Franklin's Polar Expedition.

still greater mass of drift-wood is found where the Mackenzie reaches the sea, in a latitude where no wood grows at present, except a few stunted willows. At the mouths of the river the alluvial matter has formed a barrier of islands and shoals, where we may expect a great formation of coal at some distant period.

The abundance of floating timber on the Mackenzie is owing, as I am informed by Dr. Richardson, to the peculiar direction and to the length of the course of this river, which runs from south to north, so that the sources of the stream lie in much warmer latitudes than its mouths. In the country, therefore, where the former are situated, the frost breaks up at an earlier season, while yet the waters in the lower part of its course are ice-bound. Hence the current of water, rushing down northward, reaches a point where the thaw has not begun, and, finding the channel of the river blocked up with ice, it overflows the banks, sweeping through forests of pines, and carrying away thousands of uprooted trees.

Drift-wood of the Mississippi.—We have already observed* that the navigation of the Mississippi is much impeded by trunks of trees half sunk in the river. On reaching the Gulf of Mexico many of them subside and are imbedded in the new strata which form the delta, but many of them float on and enter the Gulf stream. 'Tropical plants (says M. Constant Prevost) are taken up by this great current, and carried in a northerly direction, till they reach the shores of Iceland and Spitzbergen uninjured. A great portion of them are doubtless arrested on their passage, and probably always in the same inlets, or the same spots on the bottom of the ocean; in fact, wherever an eddy or calm determines their distribution, which, in this single example, extends over a space comprehended between the equator and the eightieth degree of latitude—an immense space, six times more considerable than that occupied by all Europe, and thirty times larger than France. The drifting of various substances, though regular, is not

* Vol. i. ch. xiv.

continual; it takes place by intermittance after great inundations of rivers, and in the intervals the waters may only carry sand or mud, or each of these alternately, to the same localities *.'

Drift timber on coasts of Iceland, Spitzbergen, &c.—The ancient forests of Iceland, as Malte-Brun observes, have been improvidently exhausted; but, although the Icelander can obtain no timber from the land, he is supplied with it abundantly by the ocean. An immense quantity of thick trunks of pines, firs, and other trees, are thrown upon the northern coast of the island, especially upon North Cape and Cape Langaness, and are then carried by the waves along these two promontories to other parts of the coast, so as to afford sufficiency of wood for fuel and for constructing boats. Timber is also carried to the shores of Labrador and Greenland; and Crantz assures us that the masses of floating wood thrown by the waves upon the island of John de Mayen often equal the whole of that island in extent †.

In a similar manner the bays of Spitzbergen are filled with drift-wood, which accumulates also upon those parts of the coast of Siberia that are exposed to the east, consisting of larch trees, pines, Siberian cedars, firs, and Fernambucco and Campeachy woods. These trunks appear to have been swept away by the great rivers of Asia and America. Some of them are brought from the Gulf of Mexico, by the Bahama stream, while others are hurried forward by the current which, to the north of Siberia, constantly sets in from east to west. Some of these trees have been deprived of their bark by friction, but are in such a state of preservation as to form excellent building timber ‡. Parts of the branches and almost all the roots remain fixed to the pines which have been drifted into the North Sea,

* Mém. de la Soc. d'Hist. Nat. de Paris, vol. iv. p. 84.

† Malte-Brun, Geog., vol. v. part i. p. 112.—Crantz, Hist. of Greenland, tome i. pp. 50—54.

‡ Olafsen, Voyage to Iceland, tome i. Malte-Brun's Geog., vol. v. part i. p. 112.

into latitudes too cold for the growth of such timber, but the trunks are usually barked.

Lighter parts of plants carried out to sea by hurricanes.—The leaves and lighter parts of plants are seldom carried out to sea, in any part of the globe, except during tropical hurricanes among islands, and during the agitations of the atmosphere which sometimes accompany earthquakes and volcanic eruptions *.

Concluding remarks.—It will appear from these observations that, although the remains of terrestrial vegetation, borne down by aqueous causes from the land, are chiefly deposited at the bottom of lakes or at the mouths of rivers, yet a considerable quantity is drifted about in all directions by currents, and may become imbedded in any *marine* formation, or may sink down, when water-logged, to the bottom of unfathomable abysses, and there accumulate without intermixture of other substances.

It may be asked whether we have any data for inferring that the remains of a considerable proportion of the existing species of plants will be permanently preserved, so as to be hereafter recognizable, supposing the strata now in progress to be at some future period upraised? To this inquiry we may reply that there are no reasons for expecting that more than a small number of the plants now flourishing in the globe will become fossilized, since the entire habitations of a great number of them are remote from lakes and seas, and even where they grow near to large bodies of water, the circumstances are quite accidental and partial which favour the imbedding and conservation of vegetable remains. Those naturalists, therefore, who infer that the ancient flora of the globe was, at certain periods, less varied than now, merely because they have as yet discovered only a few hundred fossil species of a particular epoch, while they can enumerate more than fifty thousand living ones, are reasoning on a false basis, and their standard of comparison is not the same in the two cases.

* De la Beche, Geol. Manual, p. 477.

Imbedding of the Remains of Insects.

I have observed the elytra and other parts of beetles in a band of fissile clay, separating two beds of recent shell-marl, in the Loch of Kinnordy. Amongst these, Mr. Curtis recognized Elater lineatus and Atopa cervina, species still living in Scotland. These, as well as other remains which accompanied them, appear to belong to terrestrial, not aquatic species, and must have been carried down in muddy water during an inundation. In the lacustrine peat of the same locality, the elytra of beetles are not uncommon; but in the deposits of drained lakes generally, and in the silt of our estuaries, the relics of this class of the animal kingdom are extremely rare. In the blue clay of very modern origin of Lewes Levels, Mr. Mantell has found the Indusia, or cases of the larvæ of Phryganea, in abundance, with minute shells belonging to the genera Planorbis, Limnea, &c., adhering to them *.

When speaking of the migrations of insects, we pointed out that an immense number are floated into lakes and seas by rivers, or blown by winds far from the land; but they are so buoyant that we can only suppose them, under very peculiar circumstances, to sink to the bottom before they are either devoured by insectivorous animals or are decomposed.

Remains of Reptiles.

As the bodies of several crocodiles were found in the mud brought down to the sea by the river inundation which attended an earthquake in Java in the year 1699, we may imagine that extraordinary floods of mud may stifle many individuals of the shoals of alligators and other reptiles which frequent lakes and the deltas of rivers in tropical climates. Thousands of frogs were found leaping about among the wreck carried into the sea by the late inundations in Morayshire †; and it is evident that whenever a sea-cliff is undermined, or land is

* Trans. Geol. Soc. vol. iii. part i. p. 201, Second Series.

† Sir T. D. Lauder's Account, Second Ed., p. 312.

swept by other violent causes into the sea, land reptiles may be carried in.

Remains of Birds.

We might have anticipated that the imbedding of the remains of birds in new strata would be of very rare occurrence, for their powers of flight insure them against perishing by numerous casualties to which quadrupeds are exposed during floods; and if they chance to be drowned, or to die when swimming on the water, it will scarcely ever happen that they will be submerged so as to become preserved in sedimentary deposits. For in consequence of the hollow tubular structure of their bones and the quantity of their feathers, they are extremely light in proportion to their volume, so that when first killed they do not sink to the bottom like quadrupeds, but float on the surface until the carcass either rots away or is devoured by predaceous animals, To these causes we may ascribe the absence of any vestige of the bones of birds in the recent marl formations of Scotland; although these lakes, until the moment when they were artificially drained, were frequented by a great abundance of water-fowl.

Sir T. D. Lauder records that some aquatic birds were dashed to pieces by the impetuous waters of the Deveron, in Aberdeenshire, as they rushed through a narrow pass among the rocks during the floods of 1829 *. In this manner may torrents charged with mud occasionally deposit the remains of birds in lacustrine strata.

Imbedding of Terrestrial Quadrupeds.

River inundations recur in most climates at very irregular intervals, and expend their fury on those rich alluvial plains where herds of herbivorous quadrupeds congregate together. These animals are often surprised, and being unable to stem the current, are hurried along until they are drowned, when they sink immediately to the bottom. Here their bodies are

* Account of the Great Floods, &c., Second Ed., p. 330.

drifted along, together with sediment, into lakes or seas, and may then be covered by a mass of mud, sand, and pebbles, thrown down upon them. If there be no sediment superimposed, the gases generated by putrefaction usually cause the bodies to rise again to the surface about the ninth, or at most the fourteenth day. The pressure of a thin covering would not be sufficient to retain them at the bottom, for we see the putrid carcasses of dogs and cats, even in rivers, floating with considerable weights attached to them, and they would be still more buoyant in sea-water.

In cases where the body is so buried in drift-sand, or mud accumulated upon it, as never to rise again, the skeleton may be preserved entire; but if it comes again to the surface while in the process of putrefaction, the bones commonly fall piecemeal from the floating carcass, and may in that case become scattered at random over the bottom of a lake, estuary, or sea, so that a jaw may afterwards be found in one place, a rib in another, a humerus in a third—all included, perhaps, in a matrix of fine materials, and where there may be evidence of very slight transporting power in the current, or even of none, but simply of some chemical precipitate.

A large number of the bodies of drowned animals, if they float into the sea or a lake, especially in hot climates, are instantly devoured by sharks, alligators, and other carnivorous beasts, which may have power to digest even the bones. But during extraordinary floods, when the greatest number of land animals are destroyed, the waters are commonly so turbid, especially at the bottom of the channel, that even aquatic species are compelled to escape into some retreat where there is clearer water, lest they should be stifled. For this reason, as well as the rapidity of sedimentary deposition at such seasons, the probability of some carcasses becoming permanently imbedded is considerable.

By a flood in the Solway Firth, 1794.—One of the most memorable floods of modern date, in our island, is that which visited part of the southern borders of Scotland, on the 24th of

January, 1794, and which spread particular devastation over the country adjoining the Solway Firth.

We learn from the account of Captain Napier, that the heavy rains had swollen every stream which entered the Firth of Solway, so that the inundation not only carried away a great number of cattle and sheep, but many of the herdsmen and shepherds, washing down their bodies into the estuary. After the storm, when the flood subsided, an extraordinary spectacle was seen on a large sand-bank, called 'the beds of Esk,' where there is a meeting of the tidal waters, and where heavy bodies are usually left stranded after great floods. On this single bank were found collected together the bodies of nine black cattle, three horses, one thousand eight hundred and forty sheep, forty-five dogs, one hundred and eighty hares, besides a great number of smaller animals, and, mingled with the rest, the corpses of two men and one woman *.

By floods in Scotland, 1829.—In those more recent floods in Scotland, in August 1829, whereby a fertile district, six hundred miles in length, became a scene of dreadful desolation, a vast number of animals and plants were washed from the land, and found scattered about after the storm, around the mouths of the principal rivers. An eye-witness thus describes the scene which presented itself at the mouth of the Spey, in Morayshire. 'For several miles along the beach, crowds were employed in endeavouring to save the wood and other wreck with which the heavy rolling tide was loaded; whilst the margin of the sea was strewed with the carcasses of domestic animals, and with millions of dead hares and rabbits. Thousands of living frogs, also, swept from the fields, no one can say how far off, were observed leaping among the wreck †.'

In the Savannahs of South America.—We are informed by Humboldt, that during the periodical swellings of the large rivers in South America, great numbers of quadrupeds are

* Treatise on Practical Store Farming, p. 25.

† Sir T. D. Lauder's Account of the Great Floods in Morayshire, August 1829, p. 312, Second Ed.

annually drowned. Of the wild horses, for example, which graze in immense troops in the savannahs, thousands are said to perish when the river Apure is swollen, before they have time to reach the rising grounds of the Llanos. The mares, during the season of high water, may be seen, followed by their colts, swimming about and feeding on the grass, of which the top alone waves above the waters. In this state they are pursued by crocodiles; and their thighs frequently bear the prints of the teeth of these carnivorous reptiles. 'Such is the pliability,' observes the celebrated traveller, 'of the organization of the animals which man has subjected to his sway, that horses, cows, and other species of European origin, lead, for a time, an amphibious life, surrounded by crocodiles, water-serpents, and manatees. When the rivers return again into their beds, they roam in the savannah, which is then spread over with a fine odoriferous grass, and enjoy, as in their native climate, the renewed vegetation of spring *.'

By floods of the Ganges.—We find it continually stated, by those who describe the Ganges and Burrampooter, that these rivers carry before them, during the flood season, not only floats of reeds and timber, but dead bodies of men, deer, and oxen †.

In Java, 1699.—We have already referred to the effects of a flood which attended an earthquake in Java in 1699, when the turbid waters of the Batavian river destroyed all the fish except the carp; and when drowned buffaloes, tigers, rhinoceroses, deer, apes, and other wild beasts, were brought down to the sea-coast by the current, with several crocodiles which had been stifled in the mud ‡.

On the western side of the same island, in the territory of Goulongong, in the regencies, a more recent volcanic eruption (1821) was attended by a flood, during which the river Tjetandoy bore down hundreds of carcasses of rhinoceroses and buffaloes, and swept away more than one hundred men and

* Humboldt's Pers. Nar. vol. iv. pp. 394—396.

† Malte-Brun, Geog. vol. iii. p. 22.

‡ See vol. i. chap. 25.

women from a multitude assembled on its banks to celebrate a festival. Whether the bodies reached the sea, or were deposited, with drift matter, in some of the large intervening alluvial plains, we are not informed *.

In Virginia, 1771.—We might enumerate a great number of local deluges that have swept through the fertile lands which border on large rivers, especially in tropical countries, but we should surpass the limits of this work. We may observe, however, that the destruction of islands, in rivers, is often attended with great loss of lives. Thus, when the principal river in Virginia rose, in 1771, to the height of twenty-five feet above its ordinary level, it swept entirely away Elk Island, on which were seven hundred head of quadrupeds,—horses, oxen, sheep, and hogs,—and nearly one hundred houses †.

The reader will gather, from what we have said in a former volume respecting the deposition of sediment by aqueous causes, that the greater number of the remains of quadrupeds drifted away by rivers must be intercepted by lakes before they reach the sea, or buried in fresh-water formations near the mouths of rivers. If they are carried still farther, the probabilities are increased of their rising to the surface in a state of putrefaction, and, in that case, of being there devoured by aquatic beasts of prey, or of subsiding into some spots whither no sediment is conveyed, and, consequently, where every vestige of them will, in the course of time, disappear.

Skeletons of animals in recent shell-marl, Scotland.—In some instances, the skeletons of quadrupeds are met with abundantly in recent shell-marls in Scotland, where we cannot suppose them to have been imbedded by the action of rivers or floods. They all belong to species which now inhabit, or are known to have been indigenous in Scotland. The remains of several hundred skeletons have been procured within the last century, from five or six small lakes in Forfarshire, where shell-

* This account I had from Mr. Baumhauer, Director-General of Finances in Java.

† Scots Mag., vol. xxxiii.

marl has been worked. Those of the stag (*Cervus elaphus*) are most numerous, and if the others be arranged in the order of their relative abundance, they will follow nearly thus: the ox, the boar, the horse, the sheep, the dog, the hare, the fox, the wolf, and the cat. The beaver seems extremely rare, but it has been found in the shell-marl of Loch Marlie, in Perthshire, and in the parish of Edrom, in Berwickshire.

In the greater part of these lake deposits there are no signs of floods, and the expanse of water was originally so confined, that the smallest of the above-mentioned quadrupeds could have crossed, by swimming, from one shore to the other. Deer, and such species as take readily to the water, may often have been mired in trying to land, where the bottom was soft and quaggy, and in their efforts to escape, may have plunged deeper into the marly bottom. Some individuals, we suspect, of different species, have fallen in when crossing the frozen surface in winter, for nothing can be more treacherous than the ice when covered with snow, in consequence of the springs, which are numerous, and which, always retaining an equal temperature, cause the ice, in certain spots, to be extremely thin, while in every other part of the lake, it is strong enough to bear the heaviest weights.

Drifting of mammiferous remains by currents.—As the bones of mammalia are often so abundantly preserved in peat, and in such lakes as we have just described, the encroachments of a sea upon a coast may sometimes throw down the imbedded skeletons, so that they may be carried away by tides and currents, and entombed in subaqueous formations. Some of the smaller quadrupeds, also, which burrow in the ground, as well as reptiles and every species of plant, are liable to be cast down into the waves by this cause, which must not be overlooked, although we believe it to be of comparatively small importance amongst the numerous agents whereby terrestrial organic remains may be included in submarine strata.

CHAPTER XVI.

Imbedding of the remains of man and his works in subaqueous strata—Drifting of bodies to the sea by river-inundations—Destruction of bridges and houses—Burial of human bodies in the sea—Loss of lives by shipwreck—Circumstances under which human corpses may be preserved under a great thickness of recent deposits—Number of wrecked vessels—Durable character of many of their contents—Examples of fossil skeletons of men—Of fossil canoes, ships, and works of art—Of the chemical changes which certain metallic instruments have undergone after long submergence—Effects of the subsidence of land in imbedding cities and forests in subaqueous strata—Earthquake of Cutch in 1819—Submarine forests—Example on the coast of Hampshire—Origin of a submarine forest—Berkley's arguments for the recent date of the creation of man—Concluding remarks.

IMBEDDING OF THE REMAINS OF MAN AND HIS WORKS IN SUBAQUEOUS STRATA.

We shall now proceed to inquire in what manner the mortal remains of man and the works of his hands may be permanently preserved in subaqueous strata. Of the many hundred million human beings which perish in the course of every century on the land, every vestige is usually destroyed in the course of a few thousand years, but, of the smaller number that perish in the waters, a considerable proportion must frequently be entombed, under such circumstances, that parts of them may endure throughout entire geological epochs.

We have already seen how the bodies of men, together with those of the inferior animals, are occasionally washed down during river-inundations into seas and lakes, of which we shall now enumerate some additional examples.

Belzoni witnessed a flood on the Nile in September, 1818, where, although the river only rose three feet and a half above its ordinary level, several villages, with some hundreds of men, women, and children, were swept away *. We mentioned in

* Narrative of Discovery in Egypt, &c., London, 1820.

a former volume that a rise of six feet of water in the Ganges in 1763 was attended with a much greater loss of lives.

In the year 1771, at the time of the bursting of the Solway moss before alluded to, when the inundations in the north of England appear to have equalled the recent floods in Morayshire, a great number of houses and their inhabitants were swept away by the rivers Tyne, Can, Wear, Tees, and Greta; and no less than twenty-one bridges were destroyed in the courses of these rivers. At the village of Bywell the flood tore the dead bodies and coffins out of the churchyard, and bore them away, together with many of the living inhabitants. During the same tempest an immense number of cattle, horses, and sheep, were also transported to the sea, while the whole coast was covered with the wreck of ships. Four centuries before (in 1338), the same district had been visited by a similar continuance of heavy rains followed by disastrous floods, and it is not improbable that these catastrophes may recur periodically. As the population increases, and buildings and bridges are multiplied, we must expect that the loss of lives and property will rather augment *.

Fossilization of human bodies in the bed of the sea.—If to the hundreds of human bodies committed to the deep in the way of ordinary burial we add those of individuals lost by shipwreck, we shall find that, in the course of a single year, a great number of human remains are consigned to the subaqueous regions. We shall hereafter advert to a calculation by which it appears that more than five hundred *British* vessels alone, averaging each a burden of about one hundred and twenty tons, are wrecked, and sink to the bottom, *annually*. Of these the crews for the most part escape, although it sometimes happens that all perish. In one great naval action several thousand individuals sometimes share a watery grave.

Many of these corpses are instantly devoured by predaceous fish, sometimes before they reach the bottom; still more frequently when they rise again to the surface, and float in a state

* Scots Mag., vol. xxxiii. 1771.

of putrefaction. Many decompose on the floor of the ocean, where no sediment is thrown down upon them, but if they fall upon a reef where corals and shells are becoming agglutinated into a solid rock, or subside where the delta of a river is advancing, they may be preserved for an incalculable series of ages in these deposits.

Often at the distance of a few hundred feet from a coral reef there are no soundings at the depth of many hundred fathoms. Here, if a ship strike and be wrecked, it may soon be covered by calcareous sand and fragments of coral detached by the breakers from the summit of a submarine mountain, and which may roll down to its base. Wrecks are known to have been common for centuries near certain reefs, so that canoes, merchant vessels, and ships of war, may have sunk and have been enveloped in these situations in calcareous sand and breccia. Suppose a volcanic eruption to cover such remains with ashes and sand, and that, over the tufaceous strata resulting from these ejections, a current of lava is afterwards poured, the ships and human skeletons might then remain uninjured beneath the superincumbent rock, like the houses and works of art in the subterranean cities of Campania. That cases may have already occurred where human remains have been thus preserved in a fossil state beneath masses more than a thousand feet in thickness, is by no means improbable, for, in some volcanic archipelagos, a period of thirty or forty centuries might well suffice for such an accumulation of matter.

We stated that, at the distance of about forty miles from the base of the delta of the Ganges, there is a circular space about fifteen miles in diameter where soundings of a thousand feet sometimes fail to reach the bottom. As during the flood season the quantity of mud and sand poured by the great rivers into the Bay of Bengal is so great that the sea only recovers its transparency at the distance of sixty miles from the coast, this depression must be gradually shoaling, especially as during the monsoons the sea, loaded with mud and sand, is

beaten back in that direction towards the delta. Now, if a ship or human body sink down to the bottom in such a spot, it is by no means improbable that it may become buried under a depth of three or four thousand feet of sediment in the same number of years.

Even on that part of the floor of the ocean whither no accession of drift matter is carried (a part which we believe to constitute, at any given period, by far the larger proportion of the whole submarine area), there are circumstances accompanying a wreck which favour the conservation of skeletons. For when the vessel fills suddenly with water, especially in the night, many persons are drowned between decks and in their cabins, so that their bodies are prevented from rising again to the surface. The vessel often strikes upon an uneven bottom, and is overturned, in which case the ballast, consisting of sand, shingle, and rock, or the cargo, frequently composed of heavy and durable materials, may be thrown down upon the carcasses. In the case of ships of war, cannon, shot, and other warlike stores, may press down with their weight the timbers of the vessel when they decay, and beneath these and the metallic substances the bones of man may be preserved.

Number of wrecked vessels.—When we reflect on the number of curious monuments consigned to the bed of the ocean in the course of every naval war from the earliest times, our conceptions are greatly raised respecting the multiplicity of lasting memorials which man is leaving of his labours. During our last great struggle with France, thirty-two of our ships of the line went to the bottom in the space of twenty-two years, besides seven fifty-gun ships, eighty-six frigates, and a multitude of smaller vessels. The navies of the other European powers, France, Holland, Spain, and Denmark, were almost annihilated during the same period, so that the aggregate of their losses must have many times exceeded that of Great Britain. In every one of these ships were batteries of cannon constructed of iron or brass, whereof a great number had the dates and places of their manufacture inscribed upon them in

letters cast in metal. In each there were coins of copper, silver, and often many of gold, capable of serving as valuable historical monuments; in each were an infinite variety of instruments of the arts of war and peace, many formed of materials, such as glass and earthenware, capable of lasting for indefinite ages when once removed from the mechanical action of the waves, and buried under a mass of matter which may exclude the corroding action of sea-water.

But the reader must not imagine that the fury of war is more conducive than the peaceful spirit of commercial enterprise to the accumulation of wrecked vessels in the bed of the sea. From an examination of Lloyd's lists from the year 1793, to the commencement of 1829, it has appeared that the number of *British vessels* alone lost during that period amounted, on an average, to no less than one and a half *daily* *, a greater number than we should have anticipated, although we learn from Moreau's tables that the number of merchant vessels employed at one time in the navigation of England and Scotland, amounts to about twenty thousand, having one with another a mean burden of one hundred and twenty tons †. Out of five hundred and fifty-one ships of the royal navy lost to the country during the period above mentioned, only one hundred and sixty were taken or destroyed by the enemy, the rest having either stranded or foundered, or having been burnt by accident ‡, a striking proof that the dangers of our naval warfare, however great, may be far exceeded by the storm, the hurricane, the shoal, and all the other perils of the deep.

Durable nature of many of their contents.—Millions of dollars and other coins have been sometimes submerged in a single ship, and on these, when they happen to be enveloped in a matrix capable of protecting them from chemical changes, much information of historical interest will remain inscribed, and endure for periods as indefinite as have the delicate mark-

* I am indebted to my friend Captain W. H. Smyth, R. N., for this information.

† Cæsar Moreau's Tables of the Navigation of Great Britain.

‡ I give these results on the authority of Captain W. H. Smyth, R. N.

ings of zoophytes or lapidified plants in some of the ancient secondary rocks. In almost every large ship, moreover, there are some precious stones set in seals, and other articles of use and ornament composed of the hardest substances in nature, on which letters and various images are carved—engravings which they may retain when included in subaqueous strata, as long as a crystal preserves its natural form.

It was a splendid boast, that the deeds of the English chivalry at Agincourt made Henry's chronicle

> ——— as rich with praise
> As is the ooze and bottom of the deep
> With sunken wreck and sumless treasuries;

for it is probable that a greater number of monuments of the skill and industry of man will, in the course of ages, be collected together in the bed of the ocean, than will be seen at one time on the surface of the continents.

If our species be of as recent a date as we suppose, it will be vain to seek for the remains of man and the works of his hands imbedded in submarine strata, except in those regions where violent earthquakes are frequent, and the alterations of relative level so great, that the bed of the sea may have been converted into land within the historical era. We do not despair of the discovery of such monuments whenever those regions which have been peopled by man from the earliest ages, and which are at the same time the principal theatres of volcanic action, shall be examined by the joint skill of the antiquary and the geologist.

Power of human remains to resist decay.—There can be no doubt that human remains are as capable of resisting decay as are the harder parts of the inferior animals; and we have already cited the remark of Cuvier, that 'in ancient fields of battle the bones of men have suffered as little decomposition as those of horses which were buried in the same grave *.' In the delta of the Ganges bones of men have been found in digging a well at the depth of ninety feet †; but as that river

* Vol. i. chap. ix.

† Hoff., vol. i. p. 379.

frequently shifts its course and fills up its ancient channels, we are not called upon to suppose that these bodies are of extremely high antiquity, or that they were buried when that part of the surrounding delta where they occur was first gained from the sea.

Fossil skeletons of men.—Several skeletons of men, more or less mutilated, have been found in the West Indies, on the north-west coast of the main land of Guadaloupe, in a kind of rock which is known to be forming daily, and which consists of minute fragments of shells and corals, incrusted with a calcareous cement resembling travertin, which has also bound the different grains together. The lens shows that some of the fragments of coral composing this stone, still retain the same red colour which is seen in the reefs of living coral which surround the island. The shells belong to species of the neighbouring sea intermixed with some terrestrial kinds which now live on the island, and among them is the Bulimus Guadaloupensis of Férussac. The human skeletons still retain some of their animal matter, and all their phosphate of lime. One of them, of which the head is wanting, may now be seen in the British Museum, and another in the Royal Cabinet at Paris. According to Mr. König, the rock in which the former is inclosed is harder under the mason's saw and chisel than statuary marble. It is described as forming a kind of glacis, probably an indurated beach, which slants from the steep cliffs of the island to the sea, and is nearly all submerged at high tide.

Similar formations are in progress in the whole of the West-Indian archipelago, and they have greatly extended the plain of Cayes in St. Domingo, where fragments of vases and other human works have been found at a depth of twenty feet. In digging wells also near Catania, tools have been discovered in a rock somewhat similar.

Buried ships, canoes, and works of art.—When a vessel is stranded in shallow water, it usually becomes the nucleus of a sand-bank, as has been exemplified in several of our harbours, and this circumstance tends greatly to its preservation. About

fifty years ago, a vessel from Purbeck, laden with three hundred tons of stone, struck on a shoal off the entrance of Poole harbour and foundered; the crew were saved, but the vessel and cargo remain to this day at the bottom. Since that period the shoal at the entrance of the harbour has so extended itself in a westerly direction towards Peveril Point in Purbeck, that the navigable channel is thrown a mile nearer that Point *. The cause is obvious; the tidal current deposits the sediment with which it is charged around any object which checks its velocity. Matter also drifted along the bottom is arrested by any obstacle, and accumulates round it just as the African sand-winds, before described, raise a small hillock over the carcasses of every dead camel exposed on the surface of the desert.

We alluded, in the former volume †, to an ancient Dutch vessel, discovered in the deserted channel of the river Rother, in Sussex, of which the oak wood was much blackened, but its texture unchanged. The interior was filled with fluviatile silt, as was also the case in regard to a vessel discovered in a former bed of the Mersey, and another disinterred where the St. Katherine Docks are excavated in the alluvial plain of the Thames. In like manner many ships have been found preserved entire in modern strata, formed by the silting up of estuaries along the southern shores of the Baltic, especially in Pomerania. Between Bromberg and Nakel, for example, a vessel and two anchors in a very perfect state were dug up far from the sea ‡.

At the mouth of a river in Nova Scotia, a schooner of thirty-two tons, laden with live stock, was lying with her side to the tide, when the bore, or tidal wave, which rises there about ten feet in perpendicular height, rushed into the estuary and overturned the vessel, so that it instantly disappeared. After the tide had ebbed, the schooner was so totally buried in the sand,

* This account I received from the Honourable Charles Harris.

† Vol. i. chap. xv.

‡ Hoff., vol. i. p. 368.

that the taffrel or upper rail of the deck was alone visible *. We are informed by Leigh, that on draining Martin Meer, a lake eighteen miles in circumference, in Lancashire, a bed of marl was laid dry, wherein no fewer than eight canoes were found imbedded. In figure and dimensions they were not unlike those now used in America. In a morass about nine miles distant from this Meer, a whetstone and an axe of mixed metal were dug up †. In Ayrshire also, three canoes were found in Loch Doon some few years ago; and during the present year (1831) four others, each hewn out of separate oak trees. They were twenty-three feet in length, two and a half in depth, and nearly four feet in breadth at the stern. In the mud which filled one of them, was found a war-club of oak and a stone battle-axe.

Manner in which ships may be preserved in a deep sea.—The only examples of buried vessels to which we can obtain access, are in such situations as we have mentioned, but we are unable to examine those which have been subjected to great pressure at the bottom of a deep ocean. It is extremely possible that the submerged wood-work of ships which have sunk where the sea is two or three miles deep, has undergone greater chemical changes in an equal space of time, for the experiments of Scoresby before mentioned show that wood may at certain depths be impregnated in a single hour with salt-water, so that its specific gravity is entirely altered.

It may often happen that hot springs charged with carbonate of lime, silex and other mineral ingredients, may issue at great depths, in which case every pore of the vegetable tissue may be injected with the lapidifying liquid, whether calcareous or siliceous, before the smallest decay commences. The conversion also of wood into lignite is probably more rapid under such enormous pressure. But the change of the timber into lignite or coal would not prevent the original form of a

* Silliman's Geol. Lectures, p. 78, who cites Penn.

† Leigh's Lancashire, p. 17, A. D. 1700.

ship from being distinguished, for as we find in strata of the carboniferous era, the bark of the hollow reed-like trees converted into coal, and the central cavity filled with sandstone, so might we trace the outline of a ship in coal, and in the indurated mud, sandstone, or limestone filling the interior, we might discover instruments of human art, ballast consisting of rocks foreign to the rest of the stratum, and other contents of the ship.

Chemical changes in submerged metallic substances.—Many of the metallic substances which fall into the waters, probably lose, in the course of ages, the forms artificially imparted to them; but under many circumstances these may be preserved for indefinite periods. The cannon inclosed in a calcareous rock, drawn up from the delta of the Rhone, which is now in the museum at Montpellier, might probably have endured as long as the calcareous matrix; but even if the metallic matter had been removed and had entered into new combinations, still a mould of its original shape would have been left, corresponding to those impressions of shells which we see in rocks, from which all the carbonate of lime has been subtracted. About the year 1776, says Mr. King, some fishermen sweeping for anchors in the Gull stream, (a part of the sea near the Downs,) drew up a very curious old swivel gun, near eight feet in length. The barrel, which was about five feet long, was of brass; but the handle by which it was traversed, was about three feet in length, and the swivel and pivot on which it turned were of iron. Around these latter were formed incrustations of sand converted into a kind of stone, of an exceeding strong texture and firmness; whereas round the barrel of the gun, except where it was near adjoining to the iron, there was no such incrustation, the greater part of it being clean and in good condition, just as if it had still continued in use. In the incrusting stone, adhering to it on the outside, were a number of shells and corallines, 'just as they are often found in a fossil state.' These were all so strongly

attached, that it required as much force to separate them from the matrix, 'as to break a fragment off any hard rock *.'

In the year 1745, continues the same writer, the Fox man-of-war was stranded on the coast of East Lothian and went to pieces. About thirty-three years afterwards a violent storm laid bare a part of the wreck, and threw up near the place several masses 'consisting of iron, ropes, and balls,' covered over with ochreous sand concreted and hardened into a kind of stone. The substance of the rope was very little altered. The consolidated sand retained perfect impressions of parts of an iron ring, 'just in the same manner as impressions of extraneous fossil bodies are found in various kinds of strata †.'

After a storm in the year 1824, which occasioned a considerable shifting of the sands near St. Andrew's in Scotland, a gun barrel of ancient construction was found, which is conjectured to have belonged to one of the wrecked vessels of the Spanish armada. It is now in the museum of the Antiquarian Society of Scotland, and is encrusted over by a thin coating of sand, the grains of which are cemented by brown ferruginous matter. Attached to this coating are fragments of various shells, as of the common cardium, mya, &c.

Many other examples are recorded of iron instruments taken up from the bed of the sea near the British coasts, incased by a thick coating of conglomerate, consisting of pebbles and sand, cemented by oxide of iron.

Dr. Davy describes in the Philosophical Transactions ‡, a bronze helmet of the antique Grecian form, taken up in 1825, from a shallow part of the sea, between the citadel of Corfu and the village of Castrades. Both the interior and exterior of the helmet were partially encrusted with shells, and a deposit of carbonate of lime. The surface generally, both under the incrustation and where freed from it, was of a variegated colour, mottled with spots of green, dirty white, and red. On minute

* Phil. Trans. 1779. † Ibid., vol. lxix. 1779.
‡ 1826, part ii. p. 55.

inspection with a lens, the green and red patches proved to consist of crystals of the red oxide and carbonate of copper, and the dirty white chiefly of oxide of tin.

The mineralizing process, says Dr. Davy, which has produced these new combinations, has in general penetrated very little into the substance of the helmet. The incrustation and rust removed, the metal is found bright beneath, in some places considerably corroded in others very slightly. It proves on analysis to be copper alloyed with 18.5 per cent. of tin. Its colour is that of our common brass, and it possesses a considerable degree of flexibility:—

'It is a curious question,' he adds, 'how the crystals were formed in the helmet, and on the adhering calcareous deposit. There being no reason to suppose deposition from solution, are we not under the necessity of inferring, that the mineralizing process depends on a small motion and separation of the particles of the original compound? This motion may have been due to the operation of electro-chemical powers which may have separated the different metals of the alloy.

Effects of the subsidence of land in imbedding cities and forests in subaqueous strata.

We have hitherto considered the transportation of plants and animals from the land by *aqueous* agents, and their inhumation in lacustrine or submarine deposits, and we may now inquire what tendency the subsidence of tracts of land by *earthquakes* may have to produce analogous effects. Several examples of the sinking down of buildings and portions of towns near the shore to various depths beneath the level of the sea during subterranean movements, were enumerated in a former volume, when we treated of the changes brought about by *inorganic* causes. The events alluded to were comprised within a brief portion of the historical period, and confined to a small number of the regions of active volcanos. Yet these authentic facts, relating merely to the last century and a half, gave indications of considerable change which must

have taken place in the physical geography of the globe. If during the earthquake of Jamaica in 1692, some of the houses in Port Royal subsided, together with the ground they stood upon, to the depth of twenty-four, thirty-six, and forty-eight feet under water, we are not to suppose that this was the only spot throughout the whole range of the coasts of that island or the bed of the surrounding sea which suffered similar depressions. If the quay at Lisbon sank at once to the depth of six hundred feet in 1755, we must not imagine that this was the only point on the shores of the peninsula where similar phenomena might have been witnessed.

If during the short period since South America has been colonized by Europeans we have proof of alterations of level at the three principal ports on the western shores, Callao, Valparaiso, and Conception *, we cannot for a moment suspect that these cities so distant from each other have been selected as the peculiar points where the desolating power of the earthquake has expended its chief fury. 'It would be a knowing arrow that could choose out the brave men from the cowards,' retorted the young Spartan, when asked if his comrades who had fallen on the field of battle were braver than he and his fellow prisoners; we might in the same manner remark that a geologist must attribute no small discrimination and malignity to the subterranean force, if he should suppose it to spare habitually a line of coast many thousand miles in length, with the exception of those few spots where populous towns have been erected. If then we consider how small is the area occupied by the sea-ports of this disturbed region,—points where alone each slight change of the relative level of the sea and land can be recognized, and reflect on the proofs in our possession of the local revolutions that have happened on the site of each port, within the last century and a half, our conceptions must be greatly exalted respecting the magnitude of the alterations which the Andes may have undergone even in the course of the last six thousand years.

* See vol. i. ante, chaps. xxiii. and xxv.

Cutch earthquake.—We cannot better illustrate the manner in which a large extent of surface may be submerged, so that the terrestrial plants and animals may become imbedded in subaqueous strata, than by referring to the earthquake of Cutch, in 1819, alluded to by us in a former volume *. It is stated that, for some years after that earthquake, the withered tamarisks and other shrubs protruded their tops above the waves, in parts of the lagoon which was formed by subsidence on the site of the village of Sindree and its environs; but after the flood of 1826 they were seen no longer. Every geologist will at once perceive that forests sunk by such subterranean movements, may become imbedded in subaqueous deposits both fluviatile and marine, and the trees may still remain erect, or sometimes the roots and part of the trunks may continue in their original position, while the current may have broken off, or levelled with the ground, their upper stems and branches.

Submarine forests.—But although a certain class of geological phenomena may be referred to the repetition of such catastrophes, we must hesitate before we call in to our aid the action of earthquakes, to explain what have been termed submarine forests, observed at various points around the shores of Great Britain. We have already hinted that the explanation of some of these may be sought in the encroachments of the sea, in estuaries, and the varying level of the tides, at distant periods on the same parts of our coast †. After examining, in 1829, the so-called submarine forest of Happisborough in Norfolk, I found that it was nothing more than a tertiary lignite of the 'Crag' period; which becomes exposed in the bed of the sea as soon as the waves sweep away the superincumbent strata of blueish clay. So great has been the advance of the sea upon our eastern shores within the last eight centuries, that whenever we find a mass of submerged timber near the sea side, or at the foot of the existing cliffs which we cannot suppose to be a mere accumulation of drift vegetable matter, we

* Vol. i. chap. xxiii. † Ibid., chap. xv.

should endeavour to find a solution of the problem, by reference to any cause rather than an earthquake. For we can scarcely doubt that the present outline of our coast, the shape of its estuaries, and the formation of its cliffs are of very modern date, probably within the human era, whereas we have no reason whatever to imagine that this part of Europe has been agitated by subterranean convulsions, capable of altering the relative level of land and sea, at so extremely recent a period.

Mr. Charles Harris discovered lately evident traces of a fir-wood, beneath the mean level of the sea, at Bournmouth in Hampshire, the formation having been laid open during a low spring tide. It is situated between the beach and a bar of sand about two hundred yards off, and extends fifty yards along the shore, cropping out from beneath the sand and shingle. It also lies in the direct line of the Bournmouth Valley, from the termination of which it is separated by two hundred yards of shingle and drift-sand. Down the valley flows a large brook, traversing near its mouth a considerable tract of rough, boggy, and heathy ground, which produces a few birch-trees, and a great abundance of the Myrica gale. On either side of the valley are low cliffs of barren sandstone and gravel. The formation itself consists of a stratum of soft peat, in which are implanted several large stumps of fir, from one to two feet in height, the roots and bases of which still retain their bark. The sap-wood of these is soft and spongy, but perfectly white, and exhibiting its original character. The heart-wood is exceedingly hard and tough, and in the larger stumps, of a greenish hue like asbestos, saturated with moisture and exhaling a strong odour of sulphuretted hydrogen. This odour, and the greenish colour are apparently dependent on an incipient formation of iron pyrites, which is proceeding with some rapidity in the peaty stratum beneath. The pyrites occurs in small concretions, enclosing both roots and fibres. In some instances it may be seen filling up the hollow stems of grass, in others it has penetrated to the heart of pieces of fir-wood, two or three inches in diameter, following the grain of

the wood and often supplying its place, so as not to be easily perceivable till broken.

Seventy-six rings of annual growth were counted in a transverse section of one of the trees, which was fourteen inches in diameter. Besides the stumps and roots of fir, rushes, and other compressed vegetable matter which occur in the peat, pieces of alder and birch are found. The peat in the centre of the formation was pierced two feet and a half, without being passed through; towards its edges, however, it is seen resting on a stratum of blueish pebbles, clay, and sand, which crops out also on its seaward side, and is precisely similar to the sand and pebbles that occur on the adjoining heaths. The whole formation was known to exist forty years since, at which period it was in the same situation, and presented the same appearance as at present.

Origin of a submarine forest.—Now as the sea is encroaching on this shore, we may suppose that at some former period the Bourne Valley extended far lower, and that its extremity consisted, as at present, of rough and boggy ground, partly clothed with fir-trees. It is also probable, that the whole of this rested on the sand and pebbles already mentioned, and that the sea, in its progressive encroachments, eventually laid bare, at low water, the foundations of this marshy ground; in this case, much of the sand, of which these foundations were composed, might have been washed out by the rapid descent of the fresh water through them, at the fall of the tide. The superstratum of vegetable matter being matted and bound together by the roots of trees, would not be washed away, but might be undermined, and thus sink down below the level of the sea, until the waves washed sand and shingle over it. This operation may also have been assisted by the occasional damming up of the brook by the sand and shingle thrown up during storms. Mr. Harris informs me that such an obstruction actually occurred in the years 1818 and 1824, and the bed of the brook was completely obliterated. On these occasions an artificial channel was immediately cut; had this, however, not been

done, the lower part of the valley would have been flooded; and by this means the under strata would have become more saturated with water, and the increased pressure would have augmented the tendency of the water to escape through them. In confirmation of this hypothesis, we may observe, that small streams of fresh water often pass under the sands of the sea-beach, so that they may be crossed dry-shod, whilst the water, where it issues again, may be seen to carry out sand and pebbles with great rapidity. That the above-described formation should have slipped from the adjoining cliffs is highly improbable, as all its parts would indicate it to lie in situ, especially the flags and rushes, which could only have grown in the bottom of the valley, where they were freely supplied with moisture.

Buildings how preserved under water.—Some of the buildings which have at different times subsided beneath the level of the sea, have been immediately covered up to a certain extent with strata of volcanic matter showered down upon them. Such was the case at Tomboro in Sumbawa, in the present century, and at the site of the Temple of Serapis, in the environs of Puzzuoli, probably in the 12th century. The entrance of a river charged with sediment in the vicinity, may still more frequently occasion the rapid envelopment of buildings in regularly stratified formations. But if no foreign matter be introduced, the buildings when once removed to a depth where the action of the waves is insensible, and where no great current happens to flow, may last for indefinite periods, and be as durable as the floor of the ocean itself, which may often be composed of the very same materials. There is no reason to doubt the tradition mentioned by the classic writers, that the submerged Grecian towns of Bura and Helice were seen under water; and I am informed by an eye-witness that eighty-eight years after the convulsion of 1692, the houses of Port Royal were still visible at the bottom of the sea *.

* Admiral Sir Charles Hamilton frequently saw the submerged houses of Port Royal in the year 1780, in that part of the harbour which lies between the

Berkley's arguments for the recent date of the creation of man.—We cannot conclude this chapter without recalling to the reader's mind a memorable passage written by Berkley a century ago, in which he inferred, on grounds which may be termed strictly geological, the recent date of the creation of man. 'To any one,' says he, 'who considers that on digging into the earth such quantities of shells, and in some places bones and horns of animals are found sound and entire, after having lain there in all probability some thousands of years; it should seem probable that guns, medals, and implements in metal or stone might have lasted entire, buried under ground forty or fifty thousand years if the world had been so old. How comes it then to pass that no remains are found, no antiquities of those numerous ages preceding the Scripture accounts of time; that no fragments of buildings, no public monuments, no intaglias, cameos, statues, basso-relievos, medals, inscriptions, utensils, or artificial works of any kind are ever discovered, which may bear testimony to the existence of those mighty empires, those successions of monarchs, heroes, and demi-gods for so many thousand years? Let us look forward and suppose ten or twenty thousand years to come, during which time we will suppose that plagues, famine, wars, and *earthquakes* shall have made great havoc in the world, is it not highly probable that at the end of such a period, pillars, vases, and statues now in being of granite, or porphyry, or jasper, (stones of such hardness as we know them to have lasted two thousand years above ground, without any considerable alteration) would bear record of these and past ages? Or that some of our current coins might then be dug up, or old walls and the foundations of buildings show themselves, as well as the shells and stones of *the primeval world*, which are preserved down to our times *.'

Concluding remarks.—That many signs of the agency of

town and the usual anchorage of men-of-war. Bryan Edwards also says in his History of the West Indies, (vol. i. p. 235, Oct. ed. 3 vols. 1801,) that in 1793 the *ruins* were visible in clear weather from the boats which sailed over them.

* Alciphron, or the Minute Philosopher, vol. ii. pp. 84, 85. 1732.

man would have lasted at least as long as 'the shells of the primeval world,' had our race been so ancient, we are as fully persuaded as Berkley; and we anticipate with confidence that many edifices and implements of human workmanship, and the skeletons of men, and casts of the human form, will continue to exist when a great part of the present mountains, continents, and seas have disappeared. Assuming the future duration of the planet to be indefinitely protracted, we can foresee no limit to the perpetuation of some of the memorials of man, which are continually entombed in the bowels of the earth or in the bed of the ocean, unless we carry forward our views to a period sufficient to allow the various causes of change both igneous and aqueous, to remodel more than once the entire crust of the earth. *One* complete revolution will be inadequate to efface every monument of our existence, for many works of art might enter again and again into the formation of successive eras, and escape obliteration even though the very rocks in which they had been for ages imbedded were destroyed, just as pebbles included in the conglomerates of one epoch often contain the organized remains of beings which flourished during a prior era.

Yet it is no less true, as a late distinguished philosopher has declared, 'that none of the works of a mortal being can be eternal *.' They are in the first place wrested from the hands of man, and lost as far as regards their subserviency to his use, by the instrumentality of those very causes which place them in situations where they are enabled to endure for indefinite periods. And even when they have been included in rocky strata, when they have been made to enter as it were into the solid framework of the globe itself, they must nevertheless eventually perish, for every year some portion of the earth's crust is shattered by earthquakes or melted by volcanic fire, or ground to dust by the moving waters on the surface. 'The river of Lethe,' as Bacon eloquently remarks, 'runneth as well above ground as below †.'

* Davy, Consolations in Travel, p. 276.

† Essay on the Vicissitude of Things.

CHAPTER XVII.

Imbedding of aquatic species in subaqueous strata—Inhumation of fresh-water plants and animals—Shell marl—Fossilized seed-vessels and stems of Chara —Recent deposits in the American lakes—Fresh-water species drifted into seas and estuaries—Lewes levels—Alternations of marine and fresh-water strata, how caused—Imbedding of marine plants and animals—Cetacea stranded on our shores—Their remains should be more conspicuous in marine alluvium than the bones of land quadrupeds—Liability of littoral and estuary testacea to be swept into the deep sea—Effects of a storm in the Firth of Forth —Burrowing shells secured from the ordinary action of waves and currents— Living testacea found at considerable depths.

IMBEDDING OF AQUATIC SPECIES IN SUBAQUEOUS STRATA.

We have hitherto treated of the imbedding of terrestrial plants and animals, and of human remains, in the deposits that are now forming beneath the waters, and we come next to consider in what manner *aquatic* species may be entombed in strata formed in their own element.

Fresh-water plants and animals.—The remains of species belonging to those genera of the animal and vegetable kingdoms which are more or less exclusively confined to fresh-water are for the most part preserved in the beds of lakes or estuaries, but they are oftentimes swept down by rivers into the sea, and there intermingled with the exuviæ of marine races. The phenomena attending their inhumation in lacustrine deposits may be sometimes revealed to our observation by the drainage of small lakes, such as are those in Scotland, which have been laid dry for the sake of obtaining shell marl for agricultural uses.

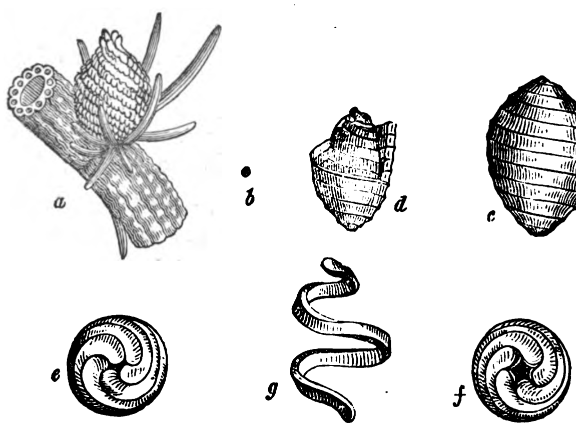
In these recent formations, as seen in Forfarshire, two or three beds of calcareous marl are sometimes observed separated from each other by layers of drift peat, sand, or fissile clay. The marl often consists almost entirely of an aggregate of shells of the genera limnea, planorbis, valvata, and cyclas, with some few others, species of all which now exist in Scotland.

A considerable proportion of the testacea appear to have died very young, and few of the shells are of a size which indicates their having attained a state of maturity. The shells are sometimes entirely decomposed, forming a pulverulent marl; sometimes they are in a state of good preservation. They are frequently intermixed with stems of charæ and other aquatic vegetables, which are matted together and compressed, forming laminæ often as thin as paper.

Fossilized seed-vessels and stems of Chara.—As the chara is an aquatic plant, which occurs frequently fossil in formations of different eras, and is often of much importance to the geologist in characterizing entire groups of strata, we shall describe the manner in which the recent species have been found in a petrified state. They occur in one of the lakes of Forfarshire, inclosed in nodules, and sometimes in a continuous stratum of a kind of travertin.

The seed-vessel of these plants is remarkably tough and

No. 2.



Seed-vessel of Chara hispida.

a, Part of the stem with the seed-vessel attached. Magnified.
b, Natural size of the seed-vessel.
c, Integument of the Gyrogonite, or petrified seed-vessel of Chara hispida, found in the Scotch marl-lakes. Magnified.
d, Section showing the nut within the integument.
e, Lower end of the integument to which the stem was attached.

hard, and consists of a membranous nut covered by an integument (fig. *d*, diagram No. 2), both of which are spirally striated or ribbed. The integument is composed of five spiral valves, of a quadrangular form (fig. *g*). In *Chara hispida,* which abounds in the lakes of Forfarshire, and which has become fossil in the Bakie Loch, each of the spiral valves of the seed-vessel turns rather more than twice round the circumference, the whole together making between ten and eleven rings. The number of these rings differs greatly in different species, but in the same appears to be very constant.

The stems of charæ occur fossil in the Scotch marl in great abundance. In some species, as in *Chara hispida,* the plant when living contains so much carbonate of lime in its vegetable organization, independently of calcareous incrustation, that it effervesces strongly with acids when dried. The stems of *Chara hispida* are longitudinally striated, with a tendency

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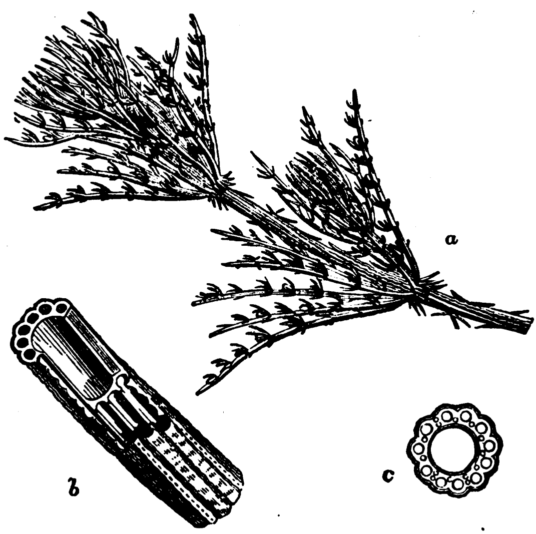


Stem and branches of Chara hispida.

a; Stem and branches of the natural size.
b, Section of the stem magnified.
c, Showing the central tube surrounded by two rings of smaller tubes.

to be spiral. These striæ, as appears to be the case with all charæ, turn always like the worm of a screw from right to left, while those of the seed-vessel wind round in a contrary direction. A cross section of the stem exhibits a curious structure, for it is composed of a large tube surrounded by smaller tubes (diagram No. 3, figs. *b*, *c*), as is seen in some extinct, as well as recent species. In the stems of several species, however, there is only a single tube *.

The valves of a small animal called cypris (*C. ornata Lam.*) occur completely fossilized like the stems of charæ, in the Scotch travertin above mentioned. This cypris inhabits the lakes and ponds of England, where it is not uncommon. Species of the same genus also occur abundantly in ancient fresh-water formations.

Recent deposits in North American lakes.—The recent strata of lacustrine origin above alluded to are of very small extent, but analogous deposits on the grandest scale have been formed in the great lakes of North America. By the subsidence of the waters of Lakes Superior and Huron, occasioned probably by the partial destruction of their barriers at some unknown period, beds of sand one hundred and fifty feet thick are exposed, below which are seen beds of clay, inclosing shells of the very species which now inhabit the lake †.

But no careful examination appears as yet to have been made of recent fresh-water formations within the tropics, where the waters teem with life, and where in the bed of a newly-drained lake the remains of the alligator, crocodile, tortoise, and perhaps some large fish, might be discovered.

Imbedding of Fresh-water Species in Estuary and Marine Deposits.

In Lewes levels.—We have sometimes an opportunity of examining the deposits which within the historical period have

* Geol. Trans., vol. ii., second series, p. 73. On Fresh-water Marl, &c. By C. Lyell, Esq.

† Dr. Bigsby, Journal of Science, &c. No. xxxvii. pp. 262, 263.

silted up some of our estuaries; and excavations made for wells and other purposes, where the sea has been finally excluded, enable us to observe the state of the organic remains in these tracts. The valley of the Ouse between Newhaven and Lewes, is one of several estuaries from which the sea has retired within the last seven or eight centuries; and here it appears, from the researches of Mr. Mantell, that strata of thirty feet and upwards in thickness have accumulated. At the top, beneath the vegetable soil, is a bed of peat about five feet thick, inclosing many trunks of trees. Next below is a stratum of blue clay containing fresh-water shells of about nine species, such as now inhabit the district. Intermixed with these was observed the skeleton of a deer. Lower down, the layers of blue clay contain, with the above-mentioned fresh-water shells, several marine species well known on our coast. In the lowest beds, often at the depth of thirty-six feet, these marine testacea occur without the slightest intermixture of fluviatile species, and amongst them the skull of the narwal, or sea-unicorn (*Monodon monoceros*), has been detected. Underneath all these deposits is a bed of pipe-clay, derived from the subjacent chalk *.

If we had no historical information respecting the former existence of an inlet of the sea in this valley, and of its gradual obliteration, the inspection of the section above described would show, as clearly as a written chronicle, the following sequence of events. First, there was a salt-water estuary peopled for many years by species of marine testacea identical with those now living, and into which some of the larger cetacea occasionally entered. Secondly, the inlet grew shallower, and the water became brackish, or alternately salt and fresh, so that the remains of fresh-water and marine shells were mingled in the blue argillaceous sediment of its bottom. Thirdly, the shoaling continued until the river-water prevailed, so that it was no longer habitable by marine testacea, but fitted

* Mantell, Geol. of Sussex, p. 285; also Catalogue of Org. Rem., Geol. Trans. v. iii. part i. p. 201. Second Series.

only for the abode of fluviatile species and aquatic insects. Fourthly, a peaty swamp or morass was formed where some trees grew, or perhaps were drifted during floods, and where terrestrial quadrupeds were mired. Finally, the soil being only flooded by the river at distant intervals, became a verdant meadow.

In delta of Ganges.—We have stated, when speaking of the delta of the Ganges, that on the sea-coast there are eight great openings, each of which has evidently, at some ancient periods, served in its turn as the principal channel of discharge. Now, as the base of the delta is two hundred miles in length, it must happen that, as often as the great volume of river-water is thrown in by a new mouth, the waters of the sea will at one point be converted from salt to fresh, and at another from fresh to salt; for, with the exception of those parts where the principal discharge takes place, the salt-water not only washes the base of the delta, but enters far into every creek and lagoon. It is evident then that repeated alternations of beds containing fresh-water shells, with others filled with corals and marine exuviæ, may here be formed, and each series may be of great thickness, as the sea on which the Gangetic delta gains is of considerable depth, and intervals of centuries elapse between each alteration in the course of the principal stream.

In delta of Indus.—Analogous phenomena must sometimes be occasioned by such alternate elevation and depression of the land as was shown to be taking place in the delta of the Indus*. But the subterranean movements affect but a small number of the deltas formed at one period on the globe; whereas, the silting up of some of the arms of great rivers and the opening of others, and the consequent variation of the points where the chief volume of their waters is discharged into the sea, are phenomena common to almost every delta.

The variety of species of testacea contained in the recent calcareous marl of Scotland, before mentioned, is very small,

* Vol. ii. first ed. p. 265; and vol. i. second ed. p. 465.

but the abundance of individuals is extremely great, a circumstance which characterizes fresh-water formations in general as compared to marine; for in the latter, as is seen on sea-beaches, coral reefs, or in the bottom of seas examined by dredging, wherever the individual shells are exceedingly numerous, there rarely fails to be a vast variety of species.

Imbedding of the Remains of Marine Plants and Animals.

Marine Plants.—We have alluded to the large banks of drift sea-weed which occur on each side of the equator in the Atlantic, Pacific, and Indian oceans *. These when they subside may often produce considerable beds of vegetable matter. In Holland submarine peat is derived from fuci, and on parts of our own coast from *Zostera marina.* In places where algæ do not generate peat, they may nevertheless leave traces of their form imprinted on argillaceous and calcareous mud, as they are usually very tough in their texture.

Cetacea.—It is not uncommon for the larger cetacea, which can only float in a considerable depth of water, to be carried during storms or high tides into estuaries, or upon low shores, where, upon the retiring of high water, they are stranded. Thus a narwal (*Monodon monoceros*) was found on the beach near Boston in Lincolnshire, in the year 1800, the whole of its body buried in the mud. A fisherman going to his boat saw the horn and tried to pull it out, when the animal began to stir itself †. An individual of the common whale (*Balæna mysticetus*), which measured seventy feet, came ashore near Peterhead, in 1682. Many individuals of the genus Balænoptera have met the same fate. We may content ourselves with referring to those cast on shore near Burnt Island, and at Alloa, recorded by Sibbald and Neill. The other individual mentioned by Sibbald, as having come ashore at Boyne, in Banffshire, was probably a Razor-back. Of the genus Ca-

* Page 81.

† Fleming's Brit. Animals, p. 37; in which work may be seen many other cases enumerated.

todon (*Cachalot*), Ray mentions a large one stranded on the west coast of Holland in 1598, and the fact is also commemorated in a Dutch engraving of the time of much merit. Sibbald, too, records that a herd of Cachalots, upwards of one hundred in number, were found stranded at Kairston, Orkney. The dead bodies of the larger cetacea are sometimes found floating on the surface of the waters, as was the case with the immense whale exhibited in London in 1831. And the carcass of a sea-cow or Lamantine (*Halicora*) was, in 1785, cast ashore near Leith. We might enumerate many more examples derived from foreign as well as British shores, but the facts above cited will suffice to show that such occurrences are not rare.

To some accident of this kind, we may refer the position of the skeleton of a whale seventy-three feet long, which was found at Airthrey, on the Forth, near Alloa, imbedded in clay twenty feet higher than the surface of the highest tide of the river Forth at the present day. From the situation of the Roman station and causeways at a small distance from the spot, it is concluded that the whale must have been stranded there at a period prior to the Christian era *.

Other fossil remains of this class have also been found in estuaries, known to have been silted up in recent times, one example of which we have already mentioned near Lewes, in Sussex. When we reflect on the facility with which these marine mammalia are thus shown to run aground upon shoals, even when there have been no great convulsions, such as hurricanes or earthquakes extending under the ocean, but merely such disturbances as the tides and storms of our seas may cause, we may be better enabled to form a sound opinion, in regard to the probability of certain geological theories, which have acquired no small share of popularity. It has been suggested, that if the ocean, displaced by the sudden upheaving of some great mountain-chain, such as the Andes, should make a transient passage over the land, a covering of alluvium might be left strewed over the hills and valleys, and that in this allu-

* Quart. Journ. of Lit. Sci. &c. No. 15, p. 172. Oct. 1819.

vium might be contained the remains of mammalia exclusively terrestrial. The skeleton of the gigantic whale, the long horn of the narwal (harder than ivory), the strong grinders of the lamantine, these and other marine relics of the era

> Omne cum Proteus pecus egit altos
> Visere montes,

might, we are told, be entirely wanting. Not one of them would be conspicuous amongst the refuse of the 'bated and retiring flood,' but instead of them we should discover the bones, tusks, and teeth of the elephant or rhinoceros, the hippopotamus, ox, and horse, with occasionally, perhaps, some intermixture of terrestrial and lacustrine shells! Such, we are taught, would be the memorials of a marine deluge sweeping over our continents! We are, however, willing to admit that they who invent causes without reference to known analogies, are guilty of no inconsistency when they claim some licence in the use which they make of their extraordinary agents. If we allow them to 'call spirits from the vasty deep' to do their bidding, and to uplift colossal chains, like the Andes, suddenly within the historical era, we must not complain that the effects of such mighty powers are not always such as the analogy of the ordinary laws of Nature would have led us to anticipate.

Marine Testacea.—The aquatic animals and plants which inhabit an estuary are liable, like the trees and land animals which people the alluvial plains of a great river, to be swept from time to time far into the deep. For as a river is perpetually shifting its course, and undermining a portion of its banks with the forests which cover them, so the marine current alters its direction from time to time, and bears away the banks of sand and mud, against which it turns its force. These banks may consist in great measure of shells peculiar to shallow, and sometimes brackish water, which may have been accumulating for centuries, until at length they are carried away and spread out along the bottom of the sea, at a depth at which they could not have lived and multiplied. Thus littoral and estuary shells are more frequently liable even than

fresh-water species, to be intermixed with the exuviæ of pelagic tribes.

After the late storm of February 4, 1831, when several vessels were wrecked in the estuary of the Forth, the current was directed against a bed of oysters with such force, that great heaps of them were thrown *alive* upon the beach, and remained above high-water mark. Many of these oysters, as also the common whelks (*buccina*), which were thrown up with them, in a living state, were worn by the long attrition of sand which had passed over them as they lay in their native bed, and which had evidently not resulted from the mere action of the tempest by which they had been cast ashore.

From these facts we may learn that the union of the two parts of a bivalve shell does not prove that it may not have been transported to a certain distance; and when we find shells worn, and with all their prominent parts rubbed off, they may still have been imbedded where they grew.

Burrowing shells.—It sometimes appears extraordinary when we observe the violence of the breakers on our coast, and see the strength of the current in removing cliffs and sweeping out new channels, that many tender and fragile shells should inhabit the sea in the immediate vicinity of this turmoil. But a great number of the bivalve testacea, and many also of the turbinated univalves, burrow in sand or mud. The solen and the cardium, for example, which are usually found in shallow water near the shore, pierce through a soft bottom without injury to their shells; and the pholas can drill a cavity through mud of considerable hardness. The species of these and many other tribes can sink, when alarmed, with considerable rapidity, often to the depth of several feet, and can also penetrate upwards again to the surface, if a mass of matter be heaped upon them. The hurricane, therefore, may expend its fury in vain, and may sweep away even the upper part of banks of sand or mud, or may roll pebbles over them, and yet these testacea may remain below secure and uninjured.

Shells become fossil at considerable depths.—We have already stated that, at the depth of 950 fathoms, between Gibraltar and Ceuta, Captain Smyth found a gravelly bottom, with fragments of broken shells carried thither probably from the comparatively shallow parts of the neighbouring straits, through which a powerful current flows. Beds of shelly sand might here, in the course of ages, be accumulated several thousand feet thick. But, without the aid of the drifting power of a current, shells may accumulate in the spot where they live and die, at great depths from the surface, if sediment be thrown down upon them; for, even in our own colder latitudes, the depths at which living marine animals abound is very considerable. Captain Vidal ascertained, by soundings lately made off Tory island, on the north-west coast of Ireland, that crustacea, star-fish, and testacea, occurred at various depths between fifty and one hundred fathoms; and he drew up dentalia from the mud of Galway bay in 230 and 240 *fathoms* water.

The same hydrographer discovered on the Rockall bank, large quantities of shells at depths varying from forty-five to one hundred and ninety fathoms. These shells were for the most part pulverized, and evidently recent, as they retained their bright colours. In the same region a bed of fish-bones was observed extending for two miles along the bottom of the sea in eighty and ninety fathoms water. At the eastern extremity also of Rockall bank fish-bones were met with, mingled with pieces of fresh shell, at the depth of 235 fathoms.

Analogous formations are in progress in the submarine tracts extending from the Shetland Isles to the north of Ireland, wherever soundings can be procured. A continuous deposit of sand and mud, replete with broken and entire shells, echini, &c., has been traced for upwards of twenty miles to the eastward of the Faroe islands, usually at the depth of from forty to one hundred fathoms. In one part of this tract (long. 6° 30′, lat. 61° 50′) fish-bones occur in extraordinary profusion, so that the lead cannot be drawn up without some verte-

bræ being attached. This bone bed, in which a few shells also are intermingled, is three miles and a half in length and forty-five fathoms under water.

In the British seas, the shells and other organic remains lie in soft mud or loose sand and gravel; whereas, in the bed of the Adriatic, Donati found them frequently enclosed in stone of recent formation, a distinction that might have been anticipated from the abundance of calcareous and other mineral springs in the Mediterranean and lands adjoining, and their absence in our own country.

During his survey of the west coast of Africa, Captain Belcher found, by frequent soundings between the twenty-third and twentieth degrees of north latitude, that the bottom of the sea, at the depth of from twenty to about fifty fathoms, consists of sand, with a great intermixture of shells, often entire, but sometimes finely comminuted. Between the eleventh and ninth degrees of north latitude, on the same coast, at soundings varying from twenty to about eighty fathoms, he brought up abundance of corals and shells mixed with sand. These also were in some parts entire, and in others worn and broken.

In all these cases it is only necessary that there should be some deposition of sedimentary matter, however minute, such as may be supplied by rivers draining a continent, or currents preying on a line of cliffs, in order that stratified formations, hundreds of feet in thickness, and replete with organic remains, should result in the course of ages.

CHAPTER XVIII.

Formation of coral reefs—They are composed of shells as well as corals—Conversion of a submerged reef into an island—Extent and thickness of coral formations—The Maldiva isles—Growth of coral not rapid—Its geological importance—Circular and oval forms of coral islands—Shape of their lagoons—Causes of their peculiar configuration—Openings into the lagoons—Why the windward side both in islands and submerged reefs is higher than the leeward—Stratification of coral formations—Extent of some reefs in the Pacific—That the subsidence by earthquakes in the Pacific, exceeds the elevation due to the same cause—Elizabeth, or Henderson's Island—Coral and shell limestones now in progress, exceed in area any known group of ancient rocks—The theory that all limestone is of animal origin considered—The hypothesis that the quantity of calcareous matter has been and is still on the increase, controverted.

FORMATION OF CORAL REEFS.

The powers of the organic creation in modifying the form and structure of those parts of the earth's crust, which may be said to be undergoing repair, or where new rock-formations are continually in progress, are most conspicuously displayed in the labours of the coral animals. We may compare the operation of these zoophytes in the ocean, to the effects produced on a smaller scale upon the land, by the plants which generate peat. In the case of the Sphagnum, the upper part vegetates while the lower portion is entering into a mineral mass, where the traces of organization usually remain, but in which life has entirely ceased. In the corals, in like manner, the more durable materials of the generation that has passed away, serve as the foundation on which living animals are continuing to rear a similar structure.

In part composed of shells.—The calcareous masses usually termed coral reefs, are by no means exclusively composed of zoophytes, but also a great variety of shells; some of the largest and heaviest of known species contributing to augment the mass. In the south Pacific, great beds of oysters, mussels,

pinnæ marinæ, and other shells, cover in great profusion almost every reef; and, on the beach of coral islands, are seen the shells of echini and the broken fragments of crustaceous animals. Large shoals of fish also are discernible through the clear blue water, and their teeth and hard palates are probably preserved, although a great portion of their soft cartilaginous bones may decay.

Of the numerous species of zoophytes which are engaged in the production of coral banks, some of the most common belong to the genera Meandrina, Caryophyllia, and Astrea, but especially the latter.

How converted into islands.—The reefs, which just raise themselves above the level of the sea, are usually of a circular or oval form, and are surrounded by a deep and often unfathomable ocean. In the centre of each, there is usually a comparatively shallow lagoon where there is still water, and where the smaller and more delicate kinds of zoophytes find a tranquil abode, while the more strong species live on the exterior margin of the isle, where a great surf usually breaks. When the reef, says M. Chamisso, a naturalist who accompanied Kotzebue, is of such a height that it remains almost dry at low water, the corals leave off building. A continuous mass of solid stone is seen composed of the shells of molluscs and echini, with their broken off prickles and fragments of coral, united by the burning sun, through the medium of the cementing calcareous sand, which has arisen from the pulverization of shells. Fragments of coral limestone are thrown up by the waves, until the ridge becomes so high, that it is covered only during some seasons of the year by the high tides. The heat of the sun often penetrates the mass of stone when it is dry, so that it splits in many places. The force of the waves is thereby enabled to separate and lift blocks of coral, frequently six feet long and three or four in thickness, and throw them upon the reef. 'After this the calcareous sand lies undisturbed, and offers to the seeds of trees and plants cast upon it by the waves, a soil upon which they rapidly grow, to overshadow its daz-

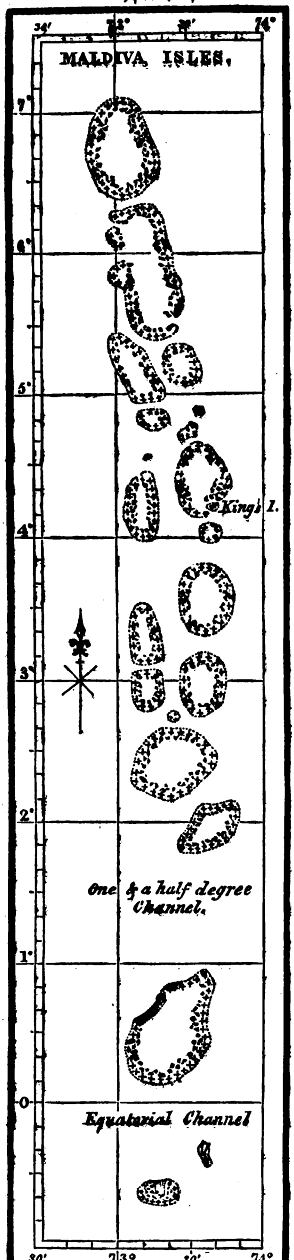
zling white surface. Entire trunks of trees, which are carried by the rivers from other countries and islands, find here, at length, a resting place after their long wanderings: with these come some small animals, such as lizards and insects, as the first inhabitants. Even before the trees form a wood, the sea-birds nestle here; strayed land-birds take refuge in the bushes; and, at a much later period, when the work has been long since completed, man also appears, builds his hut on the fruitful soil formed by the corruption of the leaves of the trees, and calls himself lord and proprietor of this new creation *.'

Extent and thickness.—The Pacific ocean, throughout a space comprehended between the thirtieth parallel of latitude on each side of the equator, is extremely productive of coral. The Arabian gulf is rapidly filling with the same, and it is said to abound in the Persian gulf. Between the coast of Malabar and that of Madagascar, there is also a great sea of coral. Flinders describes an unbroken reef three hundred and fifty miles in length, on the east coast of New Holland; and, between that country and New Guinea, Captain P. King found the coral formations to extend throughout a distance of seven hundred miles, interrupted by no intervals exceeding thirty miles in length.

Maldiva isles.—The chain of coral reefs and islets, called the Maldivas, situated in the Indian ocean to the south-west of Malabar, form a chain four hundred and eighty geographical miles in length, running due north and south. It is composed throughout of a series of circular assemblages of islets, the larger groups being from forty to fifty miles in their longest diameter. Captain Horsburgh, whose chart of these islands is subjoined, informs me that outside of each circle or atoll, as it is termed, there are coral reefs sometimes extending to the distance of two or three miles, beyond which there are no soundings at immense depths. But in the centre of each atoll there is a lagoon from fifteen to twenty fathoms deep. In the chan-

* Kotzebue's Voyages, 1815–18, vol. iii. pp. 331—3.

No. 4.



nels between the atolls, no soundings have been obtained at the depth of one hundred and fifty fathoms.

Laccadive islands.—The Laccadive islands run in the same line with the Maldivas, on the north, as do the isles of the Chagos Archipelago, on the south, so that these may be continuations of the same chain of submarine mountains, crested in a similar manner by coral limestone. It would be rash to hazard the hypothesis, that they are all the summits of volcanos, yet we might imagine, that if Java and Sumatra were submerged, they would give rise to a somewhat similar shape in the bottom of the sea; for the volcanos of those islands observe a linear direction, and are often separated from each other by intervals, corresponding to the atolls of the Maldivas; and as they rise to various heights, from five to ten thousand feet above their base, they might leave an unfathomable ocean in the intermediate spaces.

In regard to the thickness of the masses of coral, MM. Quoy and Gaimard are of opinion, that the species which contribute most actively to the formation of solid masses do not grow where the water is deeper than twenty-five or

thirty feet. But the branched madrepores, which live at considerable depth, may form the first foundation of a reef, and raise a platform on which other species may build *, and the sand and broken fragments washed by the waves from reefs may, in time, produce calcareous rocks of great thickness.

Growth of coral not rapid.—The rapidity of the growth of coral is by no means great, according to the report of the natives to Captain Beechey. In an island west of Gambier's group, our navigators observed the *Chama gigas* (Tridacna, Lam.) while the animal was yet living, so completely overgrown by coral, that a space only of two inches was left for the extremity of the shell to open and shut †. But conchologists suppose, that the chama may require thirty years or more to attain its full size, so that the fact is quite consistent with a very slow rate of increase in the calcareous reefs. In the late expedition to the Pacific no positive information could be obtained, of any channel having been filled up within a given period, and it seems established that several reefs had remained for more than half a century, at about the same depth from the surface.

The increase of coral limestone, however, may vary greatly according to the sites of mineral springs, for these we know often issue in great numbers at the bottom of the sea in volcanic regions, as in the Mediterranean, for example, where they sometimes cause the sea at great depths to be fresher than at the surface, a phenomenon also declared by the South-Sea islanders to be common in the Pacific.

Its geological importance.—But when we admit the increase of coral limestone to be slow, we are merely speaking with relation to the periods of human observation. It often happens that parisitic testacea live and die on the shells of the larger slow-moving gasteropods in the South Seas, and become entirely inclosed in an incrustation of compact limestone, while the animal, to whose habitation they are attached, crawls about

* Journ. of Geograph. Soc. of London, 1831, p. 218.

† Beechey's Voyage to the Pacific, &c. p. 157.

and bears upon his back these shells, which may be considered as already fossilized. It is, therefore, probable, that the reefs increase as fast as is compatible with the thriving state of the organic beings which chiefly contribute to their formation; and if the rate of augmentation thus implied be called, in conformity to our ordinary ideas of time, gradual and slow, it does not diminish, in the least degree, the geological importance of such calcareous masses.

Suppose the ordinary growth of coral limestone to amount to six inches in a century, it will then require three thousand years to produce a reef fifteen feet thick; but have we any ground for presuming that, at the end of that period, or of ten times thirty centuries, there will be a failure in the supply of lime, or that the polyps and molluscs will cease to act, or that the hour of the dissolution of our planet will first arrive, as the earlier geologists were fain to anticipate?

Instead of contemplating the brief annals of human events, let us turn to some natural chronometers, to the volcanic isles of the Pacific, for example, which shoot up ten or fifteen thousand feet above the level of the ocean. These islands bear evident marks of having been produced by successive volcanic eruptions; and coral reefs are sometimes found on the volcanic soil, reaching for some distance from the sea shore into the interior. When we consider the time required for the accumulation of such mountain masses of igneous matter according to the analogy of known volcanic agency, all idea of extenuating the comparative magnitude of coral limestones, on the ground of the slowness of the operations of lithogenous polyps, must instantly vanish.

Form of coral islands.—The information collected during the late expedition to the Pacific throws much additional light on the peculiarities of form and structure of coral islands. Of thirty-two of these, examined by Captain Beechey, the largest was thirty miles in diameter, and the smallest less than a mile. They were of various shapes, all formed of living coral, except one, which, although of coral formation, was raised about

eighty feet above the level of the sea, and encompassed by a reef of living coral. All were increasing their dimensions by the active operations of the lithophytes, which appeared to be gradually extending and bringing the immersed parts of their structure to the surface. Twenty-nine of the number had lagoons in their centres, which had probably existed in the others, until they were filled, in the course of time, by zoophytic and other substances.

In the above-mentioned islands, the strips of dry coral encircling the lagoons, when divested of loose sandy materials heaped upon them, are rarely elevated more than two feet above the level of the sea; and were it not for the abrupt descent of the external margin which causes the sea to break upon it, these strips would be wholly inundated. 'Those parts of the strip which are beyond the reach of the waves are no longer inhabited by the animals that reared them, but have their cells filled with a hard calcareous substance, and present a brown rugged appearance. The parts which are still immersed, or are dry at low water only, are intersected by small channels, and are so full of hollows that the tide, as it recedes, leaves small lakes of water upon them. The width of the plain or strip of dead coral, in the islands which fell under our observation, in no instance exceeded half a mile from the usual wash of the sea to the edge of the lagoon, and in general was only about three or four hundred yards *.' Beyond these limits the sides of the island descend rapidly, apparently by a succession of inclined ledges, each terminating in a precipice. The depth of the lagoons is various; in some entered by Captain Beechey, it was from twenty to thirty-eight fathoms.

Whitsunday Island.—In the annexed cut (No. 5), one of these circular islands is represented just rising above the waves, covered with the cocoa-nut and other trees, and inclosing within, a lagoon of tranquil water.

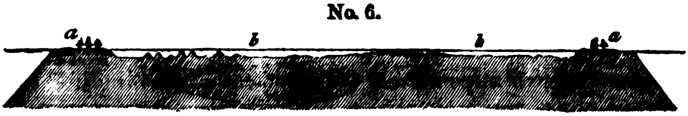
* Captain Beechey, part i. p. 188.

No. 5.

View of Whitsunday Island *.

Sections of Coral Isles.—The accompanying section will enable the reader to comprehend the usual form of such islands. (No. 6.)

No. 6.

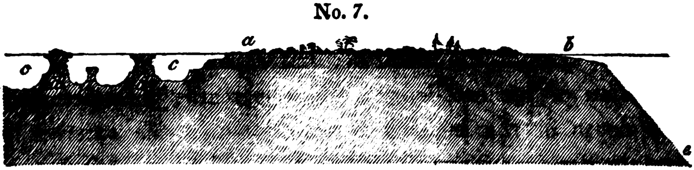


Section of a Coral Island.

a a Habitable part of the island, consisting of a strip of coral, inclosing the lagoon. *b b* The lagoon.

The subjoined cut (No. 7.) exhibits a small part of the section of a coral island on a larger scale.

No. 7.



Section of part of a Coral Island.

a b Habitable part of the island.
b e Slope of the side of the island, plunging at an angle of forty-five to the depth of fifteen hundred feet.
c c Part of the lagoon.
d d Knolls of coral in the lagoon, with overhanging masses of coral, resembling the capitals of columns.

* This plate and the section which follows are copied, by permission of Captain Beechey, from the illustrations of his valuable work before alluded to.

Origin of their peculiar configuration.—The circular or oval forms of the numerous coral isles of the Pacific, with the lagoons in their centre, naturally suggest the idea that they are nothing more than the crests of submarine volcanos, having the rims and bottoms of their craters overgrown by coral. This opinion is strengthened by the conical form of the submarine mountain, and the steep angle at which it plunges on all sides into the surrounding ocean. It is also well known that the Pacific is a great theatre of volcanic action, and every island yet examined in the wide region termed Eastern Oceanica, consists either of volcanic rocks or coral limestones.

It has also been observed that, although within the circular coral reefs, there is usually nothing discernible but a lagoon, the bottom of which is covered with coral, yet within some of these basins, as in Gambier's group, rocks composed of porous lava and other volcanic substances, rise up, resembling the two Kameni's and other eminences of igneous origin, which have been thrown up within the times of history, in the midst of the Gulf of Santorin *.

We mentioned that in volcanic archipelagos there is generally one large habitual vent, and many smaller volcanos formed at different points and at irregular intervals, all of which have usually a linear arrangement. Now in several of the groups of Eastern Oceanica there appears to be a similar disposition, the great islands, such as Otaheite, Owhyhee, and Terra del Spirito Santo, being habitual vents, and the lines of small circular coral isles which are dependent on them being very probably trains of minor volcanos, which may have been in eruption singly and at irregular intervals.

The absence of circular groups in the West Indian seas, and the tropical parts of the Atlantic, where corals are numerous, has been adduced as an additional argument, inasmuch as volcanic vents, though existing in those regions, are very inferior in importance to those in the Pacific and Indian seas †. It may be objected that the circles formed by some coral reefs or

* See vol. i. chap. 22.

† De la Beche, Geol. Man. p. 141.

groups of coral islets, varying as they do from ten to thirty miles and upwards in diameter, are so great as to preclude the idea of their being volcanic craters. In regard to this objection we may refer to what we have said in a former volume respecting the size of the so-called craters of elevation, many of which, we conceive, may be the ruins of truncated cones *.

Openings into the Lagoons.—There is yet another phenomenon attending the circular reefs, to which we have not alluded, viz., the deep narrow passage which almost invariably leads from the sea into the lagoon, and is kept open by the efflux of the sea at low tides. It is sufficient that a reef should rise a few feet above low-water mark to cause the waters to collect in the lagoon at high tide, and when the sea falls, to rush out violently at one or more points where the reef happens to be lowest or weakest. At first there are probably many openings; but the growth of the coral tends to obstruct all those which do not serve as the principal channels of discharge, so that their number is gradually reduced to a few, and often finally to one. This event is strictly analogous to that witnessed in our estuaries, where a body of salt-water accumulated during the flow, issues with great velocity at the ebb of the tide, and scours out or keeps open a deep passage through the bar, which is almost always formed at the mouth of a river.

When we controverted in our first volume Von Buch's theory of 'elevation craters,' we mentioned that a single deep gorge is described as always connecting the central cavity of such craters with the sea. The origin of this channel may be sought in the action of the tides, which affords, we think, a satisfactory explanation. Suppose a volcanic cone, having a deep crater, to be at first submarine, and to be then *gradually* elevated by earthquakes in an ocean where tides prevail, a ravine cannot fail to be cut like that which penetrates into the Caldera of the isle of Palma. The opening would at first be made on that side where the rim of the crater was originally lowest, and it would afterwards be deepened as the island rose, so as always

* See vol. i. chap. xxii.

to descend somewhat lower than the level of the sea. Captain Beechey's observations, therefore, of the effect of the tides on the coral islands, corroborate the opinion which we offered respecting the mode of formation of islands having a configuration like Palma; whereas the theory of the *sudden* upheaving of horizontal strata into a conical form, affords no explanation whatever of the *single* ravine which intersects one side of these circular islands.

In the coral reefs surrounding those volcanic islands in the Pacific which are large enough to feed small rivers, there is generally an opening or channel opposite the point where the stream of fresh water enters the sea. The depth of these channels rarely exceeds twenty-five feet, and they may be attributed, says Captain Beechey, to the aversion of the lithophytes to fresh water, and to the probable absence of the mineral matter of which they construct their habitations *.

Why the windward side highest.—But there is yet another peculiarity of the low coral islands, the explanation of which is by no means so obvious. They follow one general rule in having their windward side higher and more perfect than the other. 'At Gambier and Matilda islands this inequality is very conspicuous, the weather side of both being wooded, and of the former inhabited, while the other sides are from twenty to thirty feet under water, where, however, they might be perceived to be equally *narrow* and well defined. It is on the leeward side also that the entrances into the lagoons occur; and although they may sometimes be situated on a side that runs in the direction of the wind, as at Bow Island, yet there are none to windward.' These observations of Captain Beechey accord perfectly with those which Captain Horsburgh and other hydrographers have made in regard to the coral islands of other seas. Thus the Chagos Isles in the Indian Ocean are chiefly of a horse-shoe form, the openings being to the north-west; whereas the prevailing wind blows regularly from the south-east. From this fortunate circumstance ships can enter

* Voyage to the Pacific, &c., p. 194.

and sail out again with ease, whereas, if the narrow inlets were to windward, vessels which once entered might not succeed for months in making their way out again. The well-known security of many of these harbours, depends entirely on this fortunate peculiarity in their structure.

In what manner is this singular conformation to be accounted for? The action of the waves is seen to be the cause of the superior elevation of some reefs on their windward sides, where sand and large masses of coral rock are thrown up by the breakers; but there are a variety of cases where this cause alone is inadequate to solve the problem; for reefs submerged at considerable depths, where the movements of the sea cannot exert much power, have, nevertheless, the same conformation, the leeward being much lower than the windward side *.

I am informed by Captain King, that on examining the reefs called Rowley Shoals, which lie off the north-west coast of Australia, where the east and west monsoons prevail alternately, he found the open side of one crescent-shaped reef, the Impérieuse, turned to the east, and of another, the Mermaid, turned to the west; while a third oval reef, of the same group, was entirely submerged. This want of conformity is exactly what we should expect, where the winds vary periodically.

It seems impossible to refer the phenomenon now under consideration to any original uniformity in the configuration of submarine volcanos, on the summits of which we may suppose the coral reefs to grow; for although it is very common for craters to be broken down on one side only, we cannot imagine any cause that should breach them all in the same direction. But, if we mistake not, the difficulty will be removed if we call in another part of the volcanic agency—subsidence by earthquakes. Suppose the windward barrier to have been raised by the mechanical action of the waves to the height of two or three yards above the wall on the leeward side, and then the whole island to sink down a few fathoms, the appearances described would then be presented by the submerged reef. A repetition

* Voyage to the Pacific, &c., p. 189.

of such operations by the alternate elevation and depression of the same mass (an hypothesis strictly conformable to analogy) might produce still greater inequality in the two sides, especially as the violent efflux of the tide has probably a strong tendency to check the accumulation of the more tender corals on the leeward reef, while the action of the breakers contributes to raise the windward barrier.

Stratification of coral formations.—The calcareous formations of the Pacific are probably all stratified, although single beds may sometimes attain a great thickness. The occasional drifting of sand from the exposed parts of a reef into the lagoon or the surrounding sea, would suffice to form occasional lines of partition, especially during violent tempests which occur annually among the South-Sea islands. The decomposition of felspathic lavas may supply the current which washes and undermines the cliffs of some islands with fine clay, and this may be carried to great distances and deposited in distinct layers between calcareous masses, or may be mingled with them and form argillaceous limestones. Other divisions will arise from the arrangement of different species of testacea and zoophytes, which inhabit water of various depths, and which succeed each other as the sea deepens by the fall of the land during earthquakes, or grows shallower by elevation due to the same cause, or by the accumulation of organic substances raising the bottom.

To these causes of minor subdivision must be added another of great importance,—the ejection of volcanic ashes and sand, often carried by the wind over wide areas, and the flowing of horizontal sheets of lava, which may interrupt suddenly the growth of one coral reef, and afterwards serve as a foundation for another. An example of this kind is seen in the isle of France, where a bed of coral, ten feet thick, intervenes between two currents of lava *, and in the West Indies, in the island of Dominica, Maclure observes that ‘a bed of coral and ma-

* De la Beche, Geol. Man., p. 142. Quoy and Gaimard, Ann. des Sci. Nat., tome vi.

drepore limestone, with shells, lies horizontally on a bed of cinders, about two or three hundred feet above the level of the sea, at Rousseau, and is covered with cinders to a considerable height *.'

Reefs in the Pacific.—The reefs in the Pacific are sometimes of great extent: thus the inhabitants of Disappointment Islands, and those of Duff's Group, pay visits to each other by passing over long lines of reefs from island to island, a distance of six hundred miles and upwards. When on their route they present the appearance of troops marching upon the surface of the ocean †.

A reference to our first volume will show that a series of ordinary earthquakes might, in the course of a few centuries, convert such a tract of sea into dry land; and it is therefore a remarkable circumstance that there should be so immense an area in eastern Oceanica, studded with minute islands, without one single spot where there is a wider extent of land than belong to such islands as Otaheite, Owhyhee, and a few others, which either have been or are still the seats of active volcanos. If an equilibrium only were maintained between the upheaving and depressing force of earthquakes, large islands would very soon be formed in the Pacific; for, in that case, the growth of limestone, the flowing of lava, and the ejection of volcanic ashes, would combine with the upheaving force to form new land.

Suppose the shoal which we have described as six hundred miles in length to sink fifteen feet, and then to remain unmoved for a thousand years; during that interval the growing coral may again approach the surface. Then let the mass be re-elevated fifteen feet, so that the original reef is restored to its former position: in this case the new coral formed since the first subsidence will constitute an island six hundred miles long. An analogous result would have occurred if a lava-current

* Observations on the Geology of the West Indian Islands, Journal of Science, &c., No. X. p. 318.

† Malte-Brun's Geog., vol. iii. p. 401.

fifteen feet thick had overflowed the submerged reef. The absence, therefore, of more extensive tracts of land in the Pacific seems to show that the amount of subsidence by earthquakes exceeds in that quarter of the globe at present the elevation due to the same cause.

Elizabeth or Henderson's Island.—We mentioned that one of the thirty-two islands examined by our navigators in the late expedition was raised about eighty feet above the level of the sea *. It is called Elizabeth or Henderson's Island, and is five miles in length by one in breadth. It has a flat surface, and on all sides except the north is bounded by perpendicular cliffs about fifty feet high, composed entirely of dead coral, more or less porous, honey-combed at the surface, and hardening into a compact calcareous mass, which possesses the fracture of secondary limestone, and has a species of millepore interspersed through it. These cliffs are considerably undermined by the action of the waves, and some of them appear on

No. 8.

Elizabeth or Henderson's Island.

No. 9.

Enlarged view of part of Elizabeth or Henderson's Island.

the eve of precipitating their superincumbent weight into the sea. Those which are less injured in this way present no alternate ridges or indication of the different levels which the sea might have occupied at different periods, but a smooth surface, as if the island, which has probably been raised by volcanic agency, had been forced up by one great subterraneous convulsion †.

At the distance of a few hundred yards from this island, no

* According to some accounts, between sixty and seventy feet.

† Beechey, ibid., p. 46.

bottom could be gained with two hundred fathoms of line. It will be seen from the annexed sketch, communicated to me by Lieutenant Smyth, of the Blossom, that the trees come down to the beach towards the centre of the isle, a break which at first sight resembles the openings which usually lead into lagoons: but the trees stand on a steep slope, and no hollow of an ancient lagoon was perceived. The reader will remark that such a mass of limestone represents exactly those horizontal cappings of calcareous strata which we sometimes find on hills which have tabular summits.

As we have at present no proof that Henderson's Island has been upheaved within the historical period, we deviate somewhat from our plan when we describe it in the present chapter; but, as earthquakes are now felt from time to time in this part of the Pacific, and as indications of very recent changes of level are not wanting *, it is by no means improbable that the era of the elevation of this island may not be very remote.

Vast area of coral formations.—The calcareous masses which we have now considered, constitute, together with the associated volcanic formations, the most extensive of the groups of rocks which can be demonstrated to be now in progress. The space in the sea which they occupy is so vast, that we may safely infer that they exceed in area any group of ancient rocks which can be proved to have been of contemporaneous origin. We grant that each of the great archipelagos of the Pacific are separated by unfathomable abysses, where no zoophytes may live and no lavas flow, where not even a particle of coral sand or volcanic scoriæ may be drifted: we confine our view to the extent of reef ascertained to exist, and assume that a certain space around each volcanic or coral isle has been covered with ejections or matter from the waste of cliffs, and it will then be seen that the space occupied by these formations may equal, and perhaps exceed in area that part of our continents which has been accurately explored by the geologist.

* See Captain Beechey's Voyage to the Pacific, &c., pp. 159 and 191.

That the increase of these calcareous masses should be principally, if not entirely, confined to the shallower parts of the ocean, or in other words, to the summits of submarine ranges of mountains and elevated platforms, is a circumstance of the highest interest to the geologist; for if parts of the bed of such an ocean should be upraised, so as to form large continents, mountain-chains might appear, capped and flanked by calcareous strata of great thickness, and replete with organic remains, while in the intervening lower regions no rocks of contemporary origin would ever have existed.

Lime whence derived.—A modern writer has attempted to revive the theory of some of the earlier geologists, that all limestones have originated in organized substances. If we examine, he says, the quantity of limestone in the primary strata, it will be found to bear a much smaller proportion to the siliceous and argillaceous rocks than in the secondary, and this may have some connexion with the rarity of testaceous animals in the ancient ocean. He further infers that in consequence of the operations of animals, 'the quantity of calcareous earth deposited in the form of mud or stone is always increasing; and that as the secondary series far exceeds the primary in this respect, so a third series may hereafter arise from the depths of the sea, which may exceed the last in the proportion of its calcareous strata*.'

If these propositions went no farther than to suggest that every particle of lime that now enters into the crust of the globe, may possibly in its turn have been subservient to the purposes of life by entering into the composition of organized bodies, we should not deem the speculation improbable; but when it is hinted that lime may be an animal product combined by the powers of vitality from some simple elements, we can discover no sufficient grounds for such an hypothesis, and many facts which militate against it.

If a large pond be made, in almost any soil, and filled with rain water, it may usually become tenanted by testacea, for

* Macculloch's Syst. of Geol., vol. i. p. 219.

carbonate of lime is almost universally diffused in small quantities. But if no calcareous matter be supplied by waters flowing from the surrounding high grounds or by springs, no tufa or shell-marl are formed. The thin shells of one generation of molluscs decompose, so that their elements afford nutriment to the succeeding races; and it is only where a stream enters a lake, which may introduce a fresh supply of calcareous matter, or where the lake is fed by springs, that shells accumulate and form marl.

All the lakes in Forfarshire which have produced deposits of shell-marl, have been the sites of springs which still evolve much carbonic acid, and a small quantity of carbonate of lime. But there is no marl in Loch Fithie, near Forfar, where there are *no springs*, although that lake is surrounded by these calcareous deposits, and although, in every other respect, the site is favourable to the accumulation of aquatic testacea.

We find those charæ which secrete the largest quantity of calcareous matter in their stems, to abound near springs impregnated with carbonate of lime. We know that if the common hen be deprived altogether of calcareous nutriment, the shells of her eggs will become of too slight a consistency to protect the contents, and some birds eat chalk greedily during the breeding season.

If on the other hand we turn to the phenomena of inorganic nature, we observe that, in volcanic countries, there is an enormous evolution of carbonic acid, mixed with water or in a gaseous form, and that the springs of such districts are usually impregnated with carbonate of lime in great abundance. No one who has travelled in Tuscany, through the region of extinct volcanos and its confines, or who has seen the map recently constructed by Targioni to show the principal sites of mineral springs, can doubt for a moment, that, if this territory was submerged beneath the sea, it might supply materials for the most extensive coral reefs. The importance of these springs is not to be estimated by the magnitude of the rocks which they have thrown down on the slanting sides of hills, although

of these alone large cities might be built, nor by a coating of travertin that covers the soil in some districts for miles in length. The greater part of the calcareous matter passes down in a state of solution to the sea; and a geologist might as well assume the mass of alluvium formed in a few years in the bed of the Po, or the Ganges, to be the measure of the quantity deposited in the course of centuries in the deltas of those rivers, as conceive that the influence of the carbonated springs in Italy can be estimated by the mass of tufa precipitated by them near their sources.

It is generally admitted that the abundance of carbonate of lime given out by springs, in regions where volcanic eruptions or earthquakes prevail, is referrible to the solvent power of carbonic acid. For, as the acidulous waters percolate calcareous strata, they take up a certain portion of lime and carry it up to the surface, where, under diminished pressure in the atmosphere, it may be deposited, or, being absorbed by animals and vegetables, may be secreted by them. In Auvergne, springs charged with carbonate of lime rise through granite, in which case we must suppose the calcareous matter to be derived from some primary rock, unless we imagine it to rise up from the volcanic foci themselves.

We see no reason for supposing that the lime now on the surface, or in the crust of the earth, may not, as well as the silex, alumine, or any other mineral substance, have existed before the first organic beings were created, if it be assumed that the arrangement of the inorganic materials of our planet preceded in the order of time the introduction of the first organic inhabitants.

But if the carbonate of lime secreted by the testacea and corals of the Pacific, be chiefly derived *from below*, and if it be a very general effect of the action of subterranean heat to subtract calcareous matter from the *inferior* rocks, and to cause it to ascend to the surface, no argument can be derived in favour of the progressive increase of limestone from the magnitude of coral reefs, or the greater proportion of calca-

reous strata, in the more modern formations. A constant transfer of carbonate of lime from the inferior parts of the earth's crust to its surface, would cause throughout all future time, and for an indefinite succession of geological epochs, a preponderance of calcareous matter in the newer, as contrasted with the older formations.

DESCRIPTION OF THE PLATES AND MAP.

FRONTISPIECE.

View of part of the Valley del Bove, on the East side of the great Cone of Etna.

THIS valley is a cavity of immense depth, commencing at a short distance below the summit of Etna, and descending through that zone of the mountain where lateral eruptions are frequent. The general dip of the volcanic beds in the precipices surrounding this valley is towards the sea, but exceptions occur where lateral cones have been buried in the manner described in the first volume. The stupendous precipices surrounding this great amphitheatre vary from 600 to nearly 3000 feet in height, and they are traversed on all sides by innumerable vertical walls or dikes of compact lava, which cut through the sloping beds of lava, sand, and scoriæ, of which the great cone is formed. These dikes, which will be described in the next volume, seem all to have been produced by ancient lateral eruptions on the flanks of Etna.

The causes which have produced this great depression in the otherwise symmetrical cone of the volcano will be discussed in the third volume, and we shall merely state here that we consider the conformation of the rocky barrier encircling the cavity as entirely at variance with an hypothesis recently proposed, that the hollow was a crater of eruption from whence the scoriæ of the surrounding heights have proceeded.

We have introduced two colours into the plate, the grey to express that part of the mountain which may have been formed before the origin of the 'Val del Bove,' the red to indicate the part which has resulted from eruptions subsequent to the

formation of the valley. The great lava-currents of 1819 and 1811, described in the first volume, are seen pouring down from the higher parts of the valley, overrunning the forests of the great plain, and rising up in the foreground on the left with a rugged surface, on which small hillocks and depressions are seen, such as often characterize a lava-current immediately after its consolidation.

The small cone, No. 7, was formed in 1811, and was still smoking when I saw it in 1828. Immediately in front of it is seen another cone, formed during the same eruption. The other small volcano to the left, from which vapour is issuing, was formed, I believe, in 1819.

This sketch, which forms part of a panoramic drawing which I made in November, 1828, is merely intended to assist the reader in comprehending some geological details into which we shall hereafter enter, on the structure of the older portion of Etna, but it will give no idea of the extraordinary geological interest, still less of the picturesque grandeur of this magnificent scene of desolation. Nor is the view sufficiently extensive to exhibit the entire form of the vast amphitheatre, part only of the northern, and scarcely any of the southern boundary of which is included.

MAP

Showing the extent of Surface in Europe which has been covered by Water since the Deposition of the older Tertiary Strata. (Strata of the Paris and London Basins, &c.)

[Constructed chiefly from M. Amie Boué's Geological Map of Europe.]

This map will enable the reader to perceive at a glance the great extent of change in the physical geography of Europe which can be proved to have taken place since some of the older tertiary strata were deposited. The most ancient part of the period to which the map refers cannot be deemed very

remote, considered geologically, because the deposits of the Paris and London basins, of Auvergne, and many other districts belonging to the older tertiary epoch, are newer than the greater part of the sedimentary rocks of which the crust of the globe is composed. The species, moreover, of marine and fresh-water testacea, of which the remains are found in these formations, are not entirely distinct from such as now live; a proportion of about three in a hundred of the fossil species having been identified with species now living. Yet, notwithstanding the comparatively recent epoch to which the retrospect is carried, the variations in the distribution of land and sea depicted on the map form only a part of those which must have taken place during the period under consideration. Some approximation has merely been made to a correct estimate of the amount of *sea converted into land* in that part of Europe best known to geologists, but we cannot determine how much land has become sea during the same period; and there may have been repeated interchanges of land and water in the same places, mutations of which no account is taken in the map, and respecting the amount of which little accurate information can ever be obtained by geologists.

The proofs of submergence, during some part of the tertiary period, throughout the districts distinguished by ruled lines, are of a most unequivocal character; for the area thus described is now covered by deposits containing the remains of aquatic animals belonging to tertiary species. We have, indeed, extended the sea in two or three instances beyond these limits, because other geological data have been obtained for inferring the submergence of these tracts subsequently to the commencement of the deposition of the tertiary strata. Thus we shall explain, in the next volume, our reasons for concluding that part of the chalk of England (the north and south downs, for example, together with some other adjoining secondary tracts), continued beneath the sea until the older tertiary beds had begun to accumulate.

It is possible also that a considerable part of Caernarvon-

shire might with propriety have been represented as sea, if our information respecting the geology of that country had been more full and accurate; for marine shells have been found in sand and gravel at the height of one thousand feet above the level of the sea, on the summit of Moel Tryfane, between Snowdon and the Menai Straits. The species are apparently recent, but certainly are newer than the older tertiary epoch*.

The introduction of a small bay where the river Ribble enters into the sea in Lancashire is warranted by the newly-discovered deposit of tertiary shells covering an area of about thirty miles square in that region†.

A portion also of the primary district in Brittany is divided into islands, because it has been long known to be covered with patches of marine tertiary strata; and when I examined the disposition of these, in company with my friend, Captain S. E. Cook, R.N., in 1830, I was convinced that the sea must have covered much larger areas than are now occupied by these small and detached deposits.

The former connexion of the White Sea and the Gulf of Finland is proved by the fact that a broad band of tertiary strata extends throughout part of the intervening space. We have represented the channel as somewhat broader than the tract now occupied by the tertiary formation, because the latter is bordered on the north-west by a part of Finland, which is extremely low, and so thickly interspersed with lakes as to be nearly half covered with fresh-water.

Certain portions of the north-western shores of Norway have been left blank, because the discovery by Von Buch, Brongniart, and others, of deposits of recent shells along the coast of Norway and Sweden, at several places and at various heights above the level of the sea, attest the comparatively

* Joshua Trimmer, Esq., Proceedings of the Geological Society of London, No. 22, 1831. The shells were exhibited at the Geological Society when the memoir was read.

† See an abstract of a memoir read by Mr. Murchison, Pres. Geol. Soc., Proceedings of York Meeting, 1831.

recent date of the elevation of part of the gneiss and other primary rocks in that country, although we are unable as yet to determine how far the sea may have extended.

On the other hand, a considerable space of low land along the shores of the Gulf of Bothnia, in the Baltic, is represented as sea, because the growth of deltas on that coast, and the shallowing of the water by sedimentary deposits during the historical era, leave no room for doubt that the extent of the gulf must have been very much greater at some periods since the older tertiary epoch.

The low granitic steppe, coloured red, to the north of the Black Sea, has *not* been represented as having been under water during the tertiary period, although, from the quantity of marine tertiary strata in the surrounding districts, it is far from improbable that it has recently emerged.

We were anxious in the observations annexed to the title of this map, to guard the reader against the supposition that it was intended to represent the state of the physical geography of part of Europe at any one period. It is not a restoration of a former condition of things, but a view of the change which a certain amount of surface has undergone within a given period, an alteration so complete, that not one of the species of organic beings which now inhabit the large space designated by ruled lines, beyond the borders of the existing seas, can have lived there during some other period subsequent to the commencement of the tertiary era.

We have stated, in the first volume *, that the movements of earthquakes occasion the subsidence as well as the upraising of the surface; and that, by the alternate rising and sinking of particular spaces, at successive periods, a great area may have been entirely covered with marine deposits, although the whole may never have been beneath the waters at one time; nay, even though the relative proportion of land and sea may have continued unaltered throughout the whole period. We believe, however, that since the commencement of the tertiary

* Chap. viii.

period, the dry land in the northern hemisphere has been continually on the increase, not only because it is now greatly in excess beyond the average proportion which land generally bears to water on the globe, but because the comparison of the secondary and tertiary strata implies a passage throughout the space now occupied by Europe, from the condition of an ocean interspersed with islands to that of a large continent.

But if it were possible to represent all the vicissitudes in the distribution of land and sea that have occurred during the tertiary period, and to exhibit not only the actual existence of land where there was once sea, but also the extent of surface now submerged, which may once have been land, the map would still fail to express all the important revolutions in physical geography, which have taken place within the epoch under consideration. The oscillations of level have not merely been such as to lift up the land from below the waters to a small height above them, but in some cases a rise of several thousand feet has been effected. Thus the Alps have acquired an additional altitude of from 2000 to 4000 feet, and even in some places still more; and the Apennines owe a great part of their height (from 1000 to 2000 feet and upwards) to subterranean convulsions which have happened within the tertiary epoch.

On the other hand, some mountain chains may have been lowered during the same series of ages, in an equal degree, and shoals may have been converted into deep abysses.

It would be superfluous to point out in detail the bearing of the facts exhibited in this map, on the theories proposed in a former part of this volume, respecting the migrations of animals and plants, and the extinction of species; and it would be equally unnecessary to enlarge on the variations in *local* climate, which must have accompanied such vicissitudes in physical geography.

But the general temperature, also, of the habitable surface of the globe, as well as the local climates, may have been considerably modified by such extraordinary revolutions. The

alteration in climate, implied by a comparison of the organic remains of the older tertiary strata, and the species of living animals and plants does not appear to be so great as would be produced if the temperature of our tropics were now transferred to the temperate zone, and the temperature of the latter to the arctic. We do not, therefore, anticipate that the reader, who has duly studied the arguments explained by us in the 6th, 7th, and 8th chapters of the first volume, will object to the *adequacy* of the cause proposed, on the score of the small quantity of geographical change during the time in question.

But if there be good reason to conclude that the change would be fully adequate, in point of the magnitude of its effects, this cause, we conceive, ought to supersede every other of a purely speculative nature, until some argument can be adduced to prove that the change has not acted in the right direction *.

Some persons, but slightly acquainted with the present state of geology, have objected, that the lands in high northern latitudes have *not* been recently elevated. If they had reflected that every year we are making some new discoveries respecting the periods when tracts in the immediate neighbourhood of the great European capitals emerged from the deep, and had they sufficiently considered that the antiquity of a group of rocks has no necessary connexion with the date of its elevation, they would probably have seen the futility of such arguments. As far as we can conjecture, from the very scanty information which we possess of the geology of the arctic region, there is no want of proofs of comparatively recent alterations of level.

In conclusion, we may remark that the portion of Europe distinguished in this map by colours and ruled lines, comprises the greater part of the globe now known to geologists—almost all at least that is known in such a manner as to entitle any one to speculate on the mutations in physical geography which have taken place during the tertiary period.

* See Mr. Herschel's remarks on a change of climate.—Disc. on the Study of Nat. Phil. pp. 146 and 148.

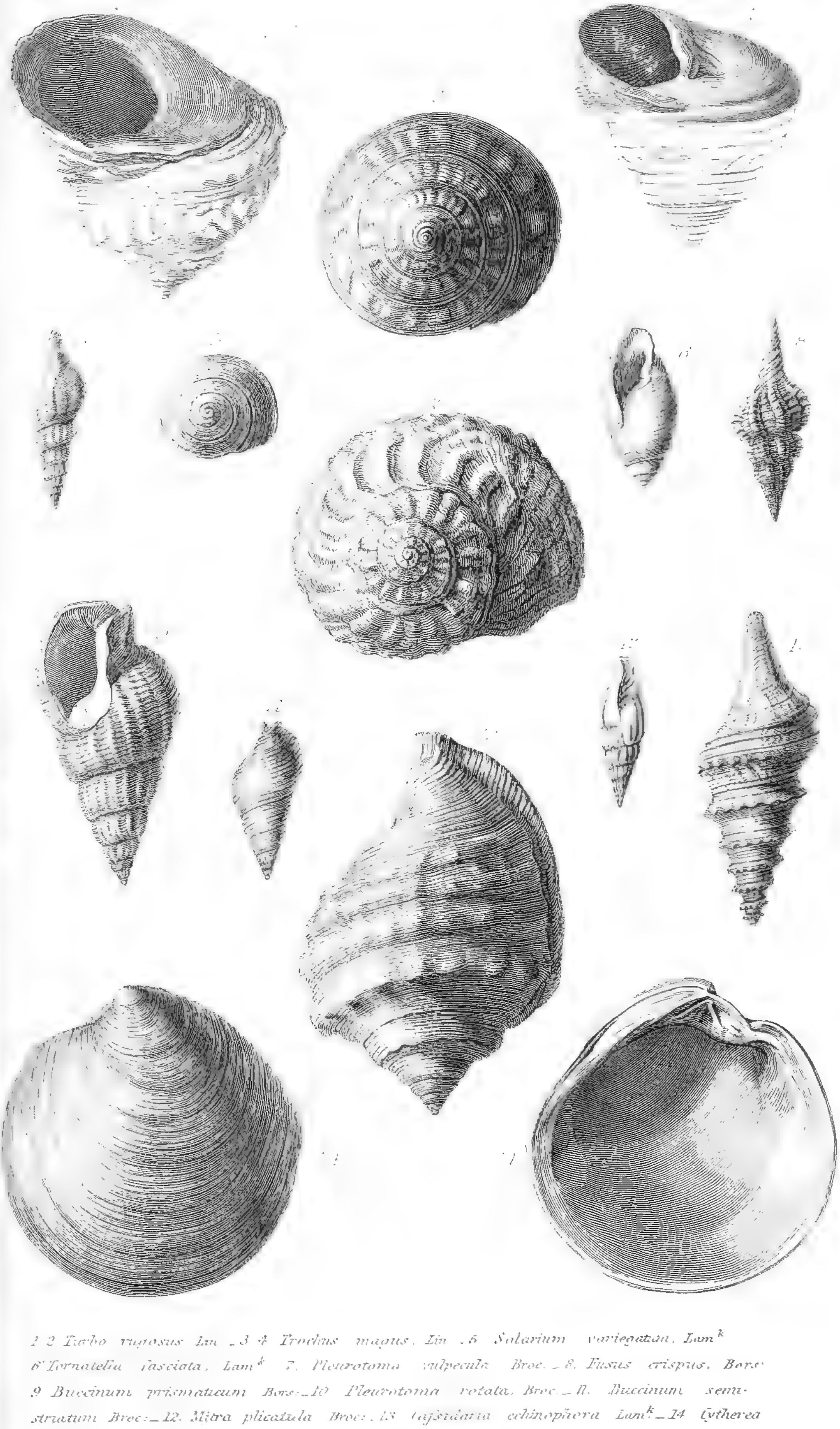
In regard to other parts of the world, we have no reason for inferring, from any data hitherto obtained, that during an equal lapse of the ages which immediately preceded our times, an equal amount of alteration of surface may not have taken place.

LIST OF WOOD-CUTS.

ERRATA.

Page 89, line 11 from the top, *for* vivid, *read* livid.
—— 103, line 10 from the top, *for* newer, *read* older.
—— 104, line 9 from the top, *for* Colosseum, *read* Coliseum.
—— 110, No. of wood-cut, *for* No. 22, *read* No. 23.
—— 111, Ditto, *for* No. 23, *read* No. 24.
—— 192, line 10 from the bottom, *for* with, *read* without.
—— 193, line 2 from the bottom, *for* Von Oyenhausen, *read* Von Oeynhausen.
—— 193, line 3 from the bottom, *for* M. Nöeggerath, *read* M. Noeggerath.
—— 197, line 19 from the top, *for* Moseberg, *read* Mosenberg.

Plate

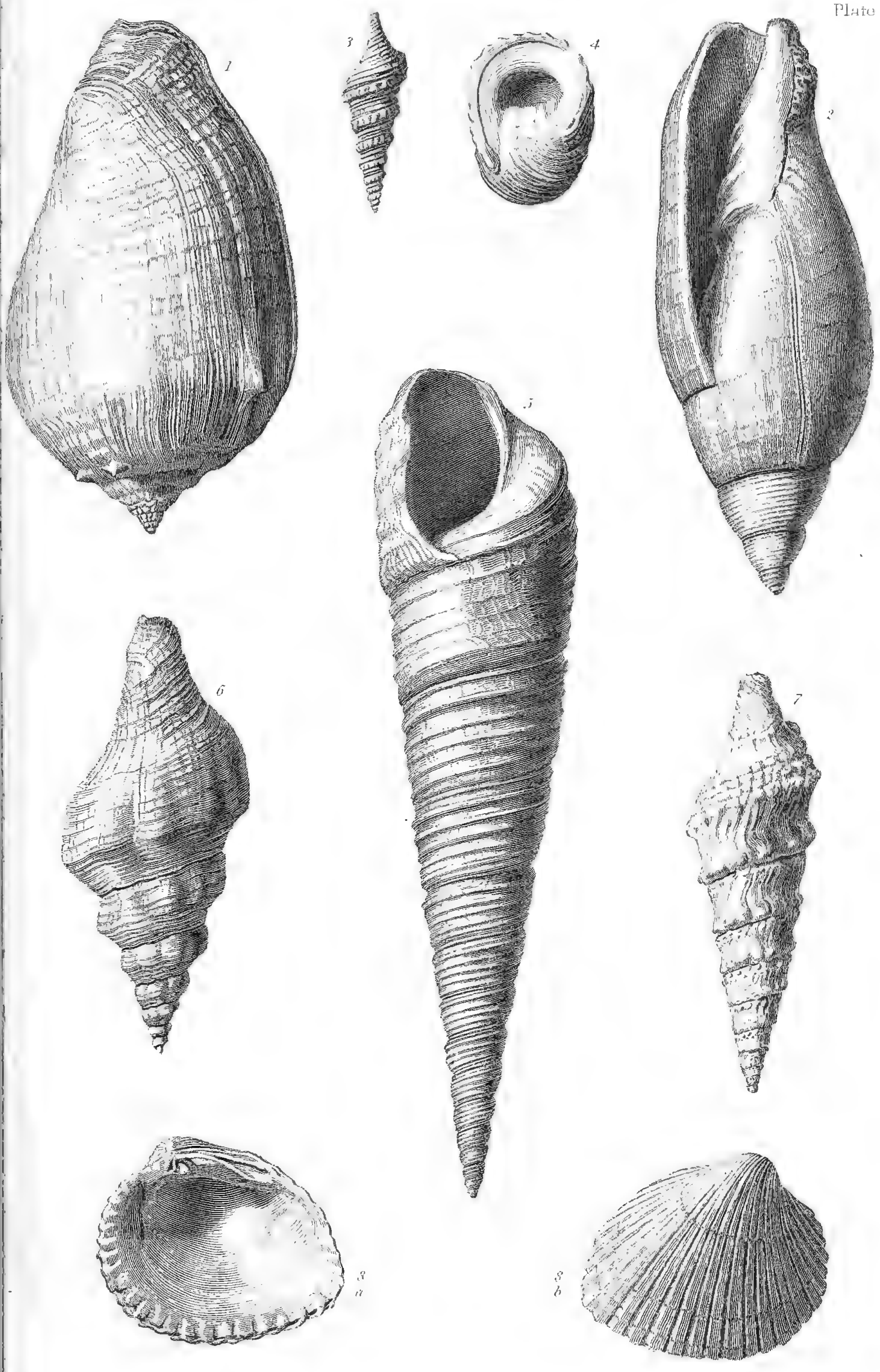


1 2 *Turbo rugosus* Lin. _3 4 *Trochus magus*. Lin. _5 *Solarium variegatum*. Lam^k
6 *Tornatella fasciata*, Lam^k 7. *Pleurotoma vulpecula* Broc. _8. *Fusus crispus*. Bors:
9 *Buccinum prismaticum* Bors:_10 *Pleurotoma rotata*. Broc._11. *Buccinum semi-striatum* Broc:_12. *Mitra plicatula* Broc:_13 *Cassidaria echinophora* Lam^k_14 *Cytherea exoleta* Lam^k var.

P. Oudart del. J. Basire sc.

London, Published by John Murray Dec^r 1831

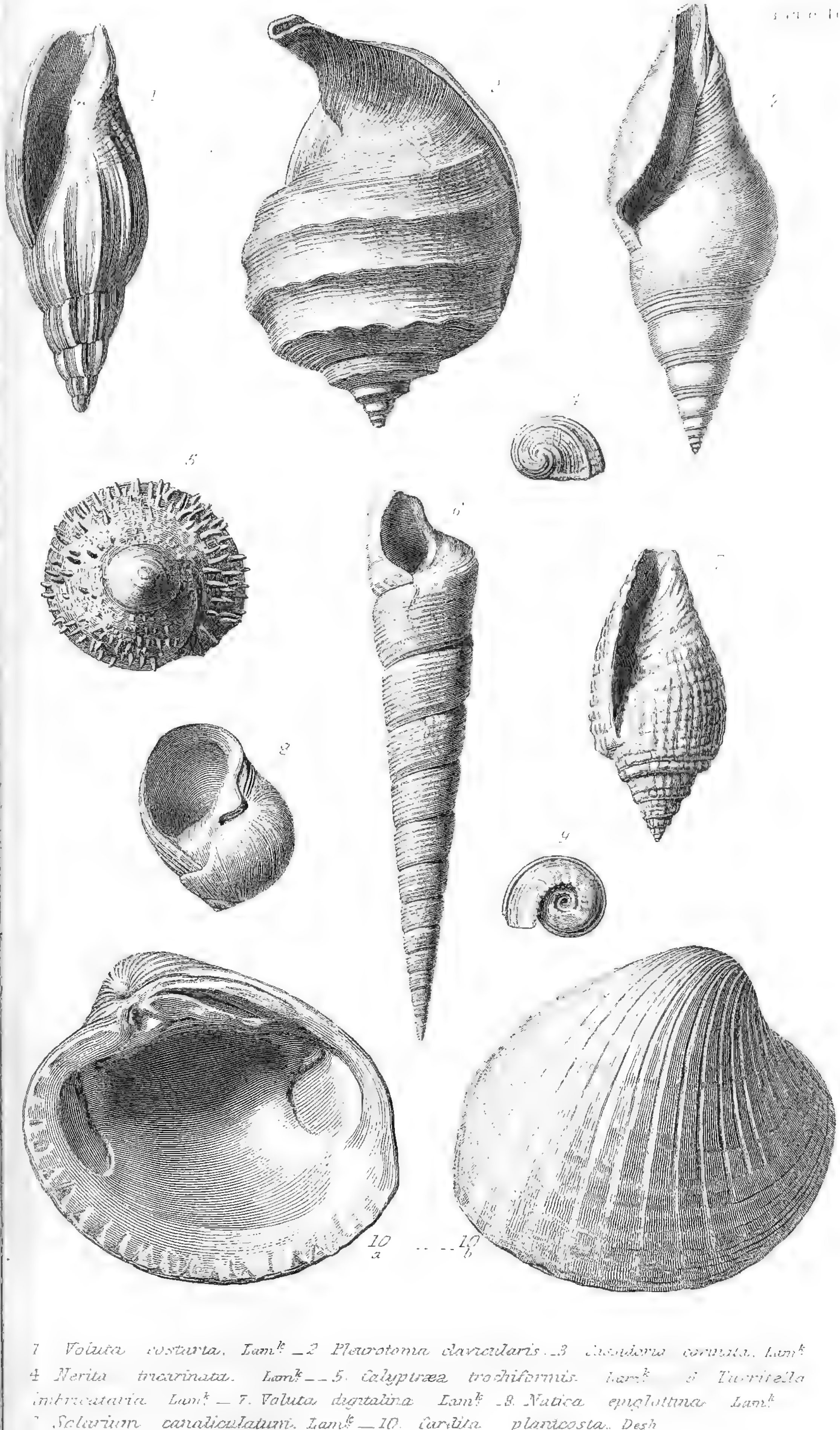
Plate II



1. Voluta rarispina, Lamk. — 2. Mitra Dufresnei, Bast. — 3. Pleurotoma denticula, Bast.
4. Nerita Plutonis, Brong. — 5. Turritella Proto, Bast. — 6. Fasciolaria turbinelloides, Desh.
7. Pleurotoma tuberculosa, Bast. — 8. a.b. Cardita Ajar, Brug.

F. Finlay sculp.

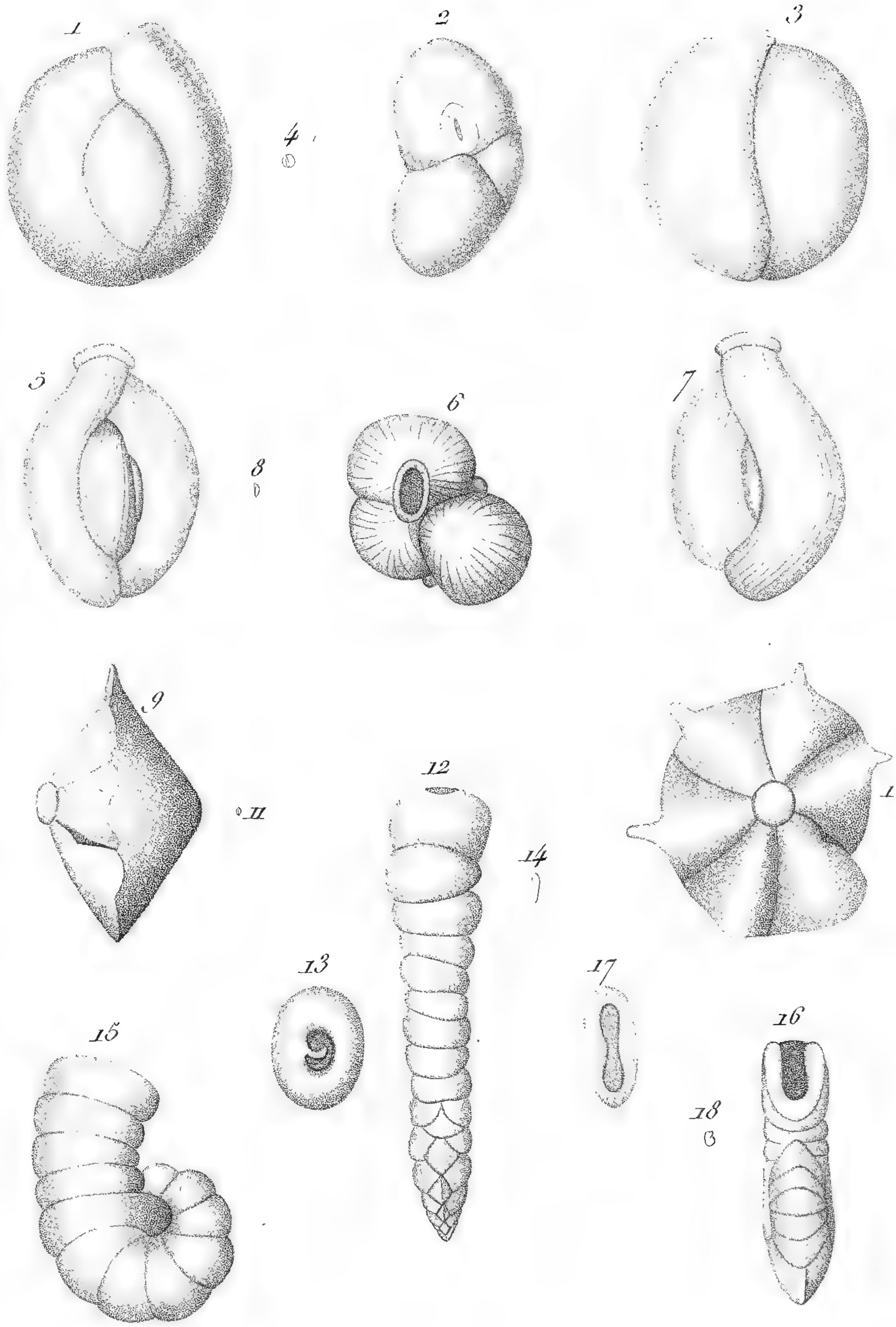
London, Published by John Murray 185[illegible].



1 *Voluta costaria.* Lamk. — 2 *Pleurotoma clavicularis.* — 3 *Cassidaria carinata.* Lamk.
4 *Nerita tricarinata.* Lamk. — 5. *Calyptræa trochiformis.* Lamk. 6 *Turritella imbricataria.* Lamk. — 7. *Voluta digitalina.* Lamk. — 8. *Natica epiglottina.* Lamk.
9 *Solarium canaliculatum.* Lamk. — 10. *Cardita planicosta.* Desh.

Gudart del.

London, Published by John Murray, 1832.

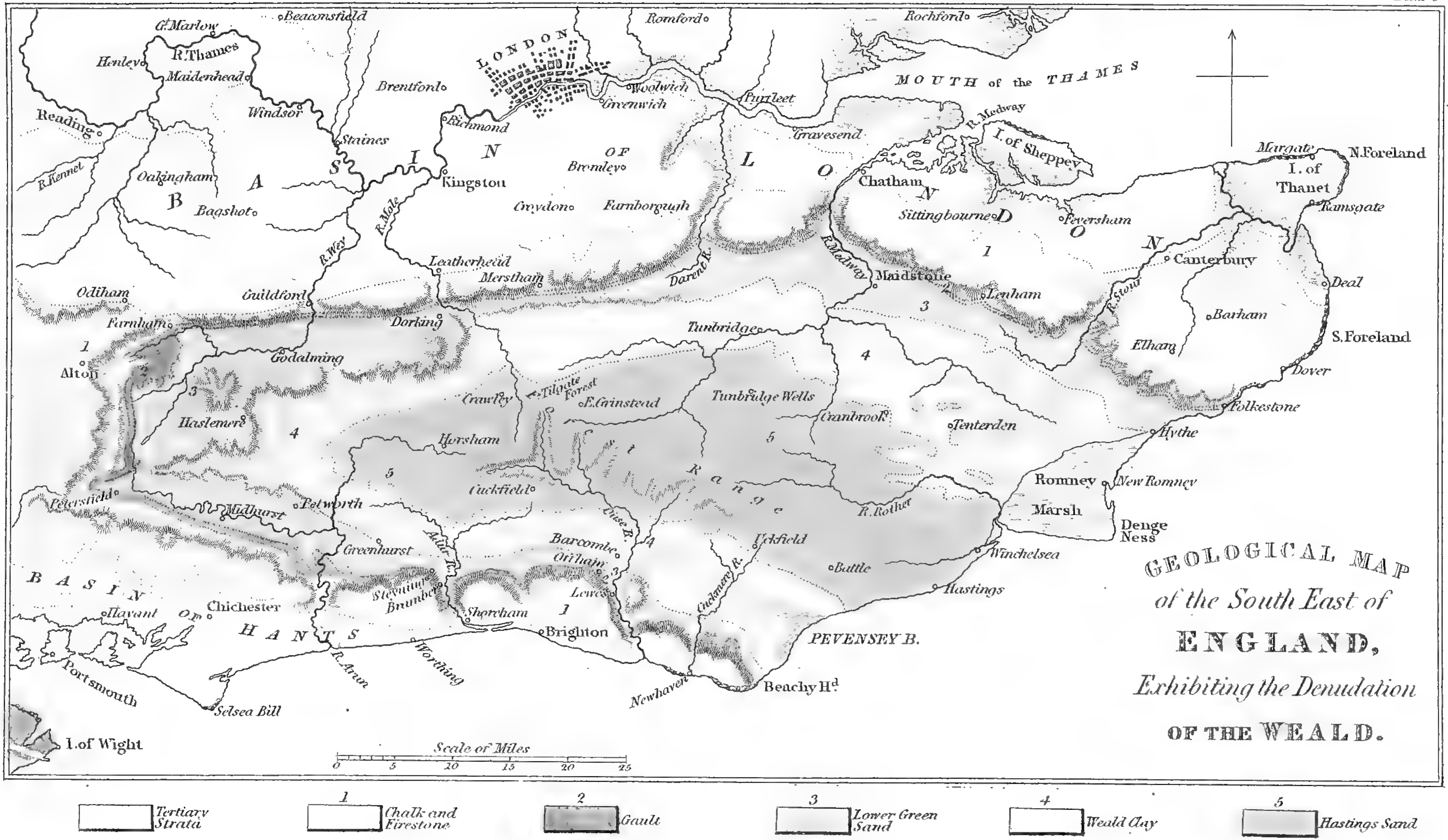


MICROSCOPIC FOSSIL SHELLS. EOCENE TERTIARY PERIOD.

PARIS BASIN

1. 2. 3. 4. *Triloculina inflata*. Desh. — 5. 6. 7. 8. *Quinqueloculina striata*. Desh.
9. 10. 11. *Calcarina rarispina*. Desh. — 12. 13. 14. *Clavulina corrugata*. Desh.
15. 16. 17. 18. *Spirolina stenostoma*. Desh.

London, Published by John Murray Dec.r 1832.


GEOLOGICAL MAP
of the South East of
ENGLAND,
Exhibiting the Denudation
OF THE WEALD.
LONDON
MOUTH of the THAMES
BASIN OF LONDON
BASIN OF HANTS
R. Thames
R. Medway
R. Mole
R. Wey
R. Arun
R. Rother
R. Stour
Ouse R.
Adur R.
Cuckmere R.
Darent R.
R. Kennet
I. of Sheppey
I. of Thanet
I. of Wight
Romney Marsh
Denge Ness
Beachy Hd.
PEVENSEY B.
N. Foreland
S. Foreland
Forest Range
Tilgate Forest
Scale of Miles
1 Chalk and Firestone
2 Gault
3 Lower Green Sand
4 Weald Clay
5 Hastings Sand
Tertiary Strata

CHAPTER I.

Connexion between the subjects treated of in the former parts of this work and those to be discussed in the present volume—Erroneous assumption of the earlier geologists respecting the discordance of the former and actual causes of change—Opposite system of inquiry adopted in this work—Illustrations from the history of the progress of Geology of the respective merits of the two systems—Habit of indulging conjectures respecting irregular and extraordinary agents not yet abandoned—Necessity in the present state of science of prefixing to a work on Geology treatises respecting the changes now in progress in the animate and inanimate world.

HAVING considered, in the preceding volumes, the actual operation of the causes of change which affect the earth's surface and its inhabitants, we are now about to enter upon a new division of our inquiry, and shall therefore offer a few preliminary observations, to fix in the reader's mind the connexion between two distinct parts of our work, and to explain in what manner the plan pursued by us differs from that more usually followed by preceding writers on Geology.

All naturalists, who have carefully examined the arrangement of the mineral masses composing the earth's crust, and who have studied their internal structure and fossil contents, have recognized therein the signs of a great succession of former changes; and the causes of these changes have been the object of anxious inquiry. As the first theorists possessed but a scanty acquaintance with the present economy of the animate and inanimate world, and the vicissitudes to which these are subject, we find them in the situation of novices, who attempt to read a history written in a foreign language, doubting about the meaning of the most ordinary terms; disputing, for

example, whether a shell was really a shell,—whether sand and pebbles were the result of aqueous trituration,—whether stratification was the effect of successive deposition from water; and a thousand other elementary questions which now appear to us so easy and simple, that we can hardly conceive them to have once afforded matter for warm and tedious controversy.

In the first volume we enumerated many prepossessions which biassed the minds of the earlier inquirers, and checked an impartial desire of arriving at truth. But of all the causes to which we alluded, no one contributed so powerfully to give rise to a false method of philosophizing as the entire unconsciousness of the first geologists of the extent of their own ignorance respecting the operations of the existing agents of change.

They imagined themselves sufficiently acquainted with the mutations now in progress in the animate and inanimate world, to entitle them at once to affirm, whether the solution of certain problems in geology could ever be derived from the observation of the actual economy of nature, and having decided that they could not, they felt themselves at liberty to indulge their imaginations, in guessing at what *might be*, rather than in inquiring *what is;* in other words, they employed themselves in conjecturing what might have been the course of nature at a remote period, rather than in the investigation of what was the course of nature in their own times.

It appeared to them more philosophical to speculate on the possibilities of the past, than patiently to explore the realities of the present, and having invented theories under the influence of such maxims, they were consistently unwilling to test their validity by the criterion of their accordance with the ordinary operations of nature. On the contrary, the claims of each new hypothesis to credibility appeared enhanced by the great contrast of the causes or forces introduced to those now developed in our terrestrial system during a period, as it has been termed, of *repose*.

Never was there a dogma more calculated to foster indolence,

and to blunt the keen edge of curiosity, than this assumption of the discordance between the former and the existing causes of change. It produced a state of mind unfavourable in the highest conceivable degree to the candid reception of the evidence of those minute, but incessant mutations, which every part of the earth's surface is undergoing, and by which the condition of its living inhabitants is continually made to vary. The student, instead of being encouraged with the hope of interpreting the enigmas presented to him in the earth's structure,—instead of being prompted to undertake laborious inquiries into the natural history of the organic world, and the complicated effects of the igneous and aqueous causes now in operation, was taught to despond from the first. Geology, it was affirmed, could never rise to the rank of an exact science,—the greater number of phenomena must for ever remain inexplicable, or only be partially elucidated by ingenious conjectures. Even the mystery which invested the subject was said to constitute one of its principal charms, affording, as it did, full scope to the fancy to indulge in a boundless field of speculation.

The course directly opposed to these theoretical views consists in an earnest and patient endeavour to reconcile the former indications of change with the evidence of gradual mutations now in progress; restricting us, in the first instance, to known causes, and then speculating on those which may be in activity in regions inaccessible to us. It seeks an interpretation of geological monuments by comparing the changes of which they give evidence with the vicissitudes now in progress, or *which may be* in progress.

We shall give a few examples in illustration of the practical results already derived from the two distinct methods of theorizing, for we have now the advantage of being enabled to judge by experience of their respective merits, and by the relative value of the fruits which they have produced.

In our historical sketch of the progress of geology, the reader has seen that a controversy was maintained for more than a century, respecting the origin of fossil shells and bones—were

they organic or inorganic substances? That the latter opinion should for a long time have prevailed, and that these bodies should have been supposed to be fashioned into their present form by a plastic virtue, or some other mysterious agency, may appear absurd; but it was, perhaps, as reasonable a conjecture as could be expected from those who did not appeal, in the first instance, to the analogy of the living creation, as affording the only source of authentic information. It was only by an accurate examination of living testacea, and by a comparison of the osteology of the existing vertebrated animals with the remains found entombed in ancient strata, that this favourite dogma was exploded, and all were, at length, persuaded that these substances were exclusively of organic origin.

In like manner, when a discussion had arisen as to the nature of basalt and other mineral masses, evidently constituting a particular class of rocks, the popular opinion inclined to a belief that they were of aqueous, not of igneous origin. These rocks, it was said, might have been precipitated from an aqueous solution, from a chaotic fluid, or an ocean which rose over the continents, charged with the requisite mineral ingredients. All are now agreed that it would have been impossible for human ingenuity to invent a theory more distant from the truth; yet we must cease to wonder, on that account, that it gained so many proselytes, when we remember that its claims to probability arose partly from its confirming the assumed want of all analogy between geological causes and those now in action.

By what train of investigation were all theorists brought round at length to an opposite opinion, and induced to assent to the igneous origin of these formations? By an examination of the structure of active volcanos, the mineral composition of their lavas and ejections, and by comparing the undoubted products of fire with the ancient rocks in question.

We shall conclude with one more example. When the organic origin of fossil shells had been conceded, their occurrence in strata forming some of the loftiest mountains in the world, was admitted as a proof of a great alteration of the

relative level of sea and land, and doubts were then entertained whether this change might be accounted for by the partial drying up of the ocean, or by the elevation of the solid land. The former hypothesis, although afterwards abandoned by general consent, was at first embraced by a vast majority. A multitude of ingenious speculations were hazarded to show how the level of the ocean might have been depressed, and when these theories had all failed, the inquiry, as to what vicissitudes of this nature might now be taking place, was, as usual, resorted to in the last instance. The question was agitated, whether any changes in the level of sea and land had occurred during the historical period, and, by patient research, it was soon discovered that considerable tracts of land had been permanently elevated and depressed, while the level of the ocean remained unaltered. It was therefore necessary to reverse the doctrine which had acquired so much popularity, and the unexpected solution of a problem at first regarded as so enigmatical, gave perhaps the strongest stimulus ever yet afforded to investigate the ordinary operations of nature. For it must have appeared almost as improbable to the earlier geologists, that the laws of earthquakes should one day throw light on the origin of mountains, as it must to the first astronomers, that the fall of an apple should assist in explaining the motions of the moon.

Of late years the points of discussion in geology have been transferred to new questions, and those, for the most part, of a higher and more general nature; but, notwithstanding the repeated warnings of experience, the ancient method of philosophising has not been materially modified.

We are now, for the most part, agreed as to what rocks are of igneous, and what of aqueous origin,—in what manner fossil shells, whether of the sea or of lakes, have been imbedded in strata,—how sand may have been converted into sandstone,—and are unanimous as to other propositions which are not of a complicated nature; but when we ascend to those of a higher order, we find as little disposition, as formerly, to make a strenuous effort, in the first instance, to search out an explanation in

the ordinary economy of Nature. If, for example, we seek for the causes why mineral masses are associated together in certain groups; why they are arranged in a certain order which is never inverted; why there are many breaks in the continuity of the series; why different organic remains are found in distinct sets of strata; why there is often an abrupt passage from an assemblage of species contained in one formation to that in another immediately superimposed,—when these and other topics of an equally extensive kind are discussed, we find the habit of indulging conjectures, respecting irregular and extraordinary causes, to be still in full force.

We hear of sudden and violent revolutions of the globe, of the instantaneous elevation of mountain chains, of paroxysms of volcanic energy, declining according to some, and according to others increasing in violence, from the earliest to the latest ages. We are also told of general catastrophes and a succession of deluges, of the alternation of periods of repose and disorder, of the refrigeration of the globe, of the sudden annihilation of whole races of animals and plants, and other hypotheses, in which we see the ancient spirit of speculation revived, and a desire manifested to cut, rather than patiently to untie, the Gordian knot.

In our attempt to unravel these difficult questions, we shall adopt a different course, restricting ourselves to the known or possible operations of existing causes; feeling assured that we have not yet exhausted the resources which the study of the present course of nature may provide, and therefore that we are not authorized, in the infancy of our science, to recur to extraordinary agents. We shall adhere to this plan, not only on the grounds explained in the first volume, but because, as we have above stated, history informs us that this method has always put geologists on the road that leads to truth,—suggesting views which, although imperfect at first, have been found capable of improvement, until at last adopted by universal consent. On the other hand, the opposite method, that of speculating on a former distinct state of things, has led invariably to a multitude of contradictory systems, which have been

overthrown one after the other,—which have been found quite incapable of modification,—and which are often required to be precisely reversed.

In regard to the subjects treated of in our first two volumes, if systematic treatises had been written on these topics, we should willingly have entered at once upon the description of geological monuments properly so called, referring to other authors for the elucidation of elementary and collateral questions, just as we shall appeal to the best authorities in conchology and comparative anatomy, in proof of many positions which, but for the labours of naturalists devoted to these departments, would have demanded long digressions. When we find it asserted, for example, that the bones of a fossil animal at Œningen were those of man, and the fact adduced as a proof of the deluge, we are now able at once to dismiss the argument as nugatory, and to affirm the skeleton to be that of a reptile, on the authority of an able anatomist; and when we find among ancient writers the opinion of the gigantic stature of the human race in times of old, grounded on the magnitude of certain fossil teeth and bones, we are able to affirm these remains to belong to the elephant and rhinoceros, on the same authority.

But since in our attempt to solve geological problems, we shall be called upon to refer to the operation of aqueous and igneous causes, the geographical distribution of animals and plants, the real existence of species, their successive extinction, and so forth, we were under the necessity of collecting together a variety of facts, and of entering into long trains of reasoning, which could only be accomplished in preliminary treatises.

These topics we regard as constituting the alphabet and grammar of geology; not that we expect from such studies to obtain a key to the interpretation of all geological phenomena, but because they form the groundwork from which we must rise to the contemplation of more general questions relating to the complicated results to which, in an indefinite lapse of ages, the existing causes of change may give rise.

CHAPTER II.

Arrangement of the materials composing the earth's crust—The existing continents chiefly composed of subaqueous deposits—Distinction between sedimentary and volcanic rocks—Between primary, secondary, and tertiary—Origin of the primary—Transition formations—Difference between secondary and tertiary strata—Discovery of tertiary groups of successive periods—Paris basin—London and Hampshire basins—Tertiary strata of Bordeaux, Piedmont, Touraine, &c.—Subapennine beds—English crag—More recent deposits of Sicily, &c.

GENERAL ARRANGEMENT OF THE MATERIALS COMPOSING THE EARTH'S CRUST.

When we examine into the structure of the earth's crust (by which we mean the small portion of the exterior of our planet accessible to human observation), whether we pursue our investigations by aid of mining operations, or by observing the sections laid open in the sea cliffs, or in the deep ravines of mountainous countries, we discover everywhere a series of mineral masses, which are not thrown together in a confused heap, but arranged with considerable order; and even where their original position has undergone great subsequent disturbance, there still remain proofs of the order that once reigned.

We have already observed, that if we drain a lake, we frequently find at the bottom a series of recent deposits disposed with considerable regularity one above the other; the uppermost, perhaps, may be a stratum of peat, next below a more compact variety of the same, still lower a bed of laminated shell marl, alternating with peat, and then other beds of marl, divided by layers of clay. Now if a second pit be sunk through the same continuous lacustrine deposit, at some distance from the first, we often meet with nearly the same series of beds, yet with slight variations; some, for example, of the layers of sand, clay, or marl may be wanting, one or more of

them having thinned out and given place to others, or sometimes one of the masses, first examined, is observed to increase in thickness to the exclusion of other beds. Besides this limited continuity of particular strata, it is obvious that the whole assemblage must terminate somewhere; as, for example, where they reach the boundary of the original lake-basin, and where they will come in contact with the rocks which form the boundary of, and, at the same time, pass under all the recent accumulations.

In almost every estuary we may see, at low water, analogous phenomena where the current has cut away part of some newly-formed bank, consisting of a series of horizontal strata of peat, sand, clay, and, sometimes, interposed beds of shells. Each of these may often be traced over a considerable area, some extending farther than others, but all of necessity confined within the basin of the estuary. Similar remarks are applicable, on a much more extended scale, to the recent delta of a great river, like the Ganges, after the periodical inundations have subsided, and when sections are exposed of the river-banks and the cliffs of numerous islands, in which horizontal beds of clay and sand may be traced over an area many hundred miles in length, and more than a hundred in breadth.

Subaqueous deposits. The greater part of our continents are evidently composed of subaqueous deposits; and in the manner of their arrangement we discover many characters precisely similar to those above described; but the different groups of strata are, for the most part, on a greater scale, both in regard to depth and area, than any observable in the new formations of lakes, deltas, or estuaries. We find, for example, beds of limestone several hundred feet in thickness, containing imbedded corals and shells, stretching from one country to another, yet always giving place, at length, to a distinct set of strata, which either rise up from under it like the rocks before alluded to as forming the borders of a lake, or cover and conceal it. In other places, we find beds of pebbles, and sand, or of clay of great thickness. The different formations composed of these materials

usually contain some peculiar organic remains; as, for example, certain species of shells and corals, or certain plants.

Volcanic rocks. Besides these strata of aqueous origin, we find other rocks which are immediately recognized to be the products of fire, from their exact resemblance to those which have been produced in modern times by volcanos, and thus we immediately establish two distinct orders of mineral masses composing the crust of the globe—the sedimentary and the volcanic.

Primary rocks. But if we investigate a large portion of a continent which contains within it a lofty mountain range, we rarely fail to discover another class, very distinct from either of those above alluded to, and which we can neither assimilate to deposits such as are now accumulated in lakes or seas, nor to those generated by ordinary volcanic action. The class alluded to, consists of granite, granitic schist, roofing slate, and many other rocks, of a much more compact and crystalline texture than the sedimentary and volcanic divisions before mentioned. In the unstratified portion of these crystalline rocks, as in the granite for example, no organic fossil remains have ever been discovered, and only a few faint traces of them in some of the *stratified* masses of the same class; for we should state, that a considerable portion of these rocks are divided, not only into strata, but into laminæ, so closely imitating the internal arrangement of well-known aqueous deposits, as to leave scarcely any reasonable doubt that they owe this part of their texture to similar causes.

These remarkable formations have been called *primitive*, from being supposed to constitute the most ancient mineral productions known to us, and from a notion that they originated before the earth was inhabited by living beings, and while yet the planet was in a nascent state. Their high relative antiquity is indisputable; for in the oldest sedimentary strata, containing organic remains, we often meet with rounded pebbles of the older crystalline rocks, which must therefore have been consolidated before the derivative strata were formed out of

their ruins. They rise up from beneath the rocks of mechanical origin, entering into the structure of lofty mountains, so as to constitute, at the same time, the lowest and the most elevated portions of the crust of the globe.

Origin of primary rocks. Nothing strictly analogous to these ancient formations can now be seen in the progress of formation on the habitable surface of the earth, nothing, at least, within the range of human observation. The first speculators, however, in Geology, found no difficulty in explaining their origin, by supposing a former condition of the planet perfectly distinct from the present, when certain chemical processes were developed on a great scale, and whereby crystalline precipitates were formed, some more suddenly, in huge amorphous masses, such as granite; others by successive deposition and with a foliated and stratified structure, as in the rocks termed gneiss and mica-schist. A great part of these views have since been entirely abandoned, more especially with regard to the origin of granite, but it is interesting to trace the train of reasoning by which they were suggested. First, the stratified primitive rocks exhibited, as we before mentioned, well-defined marks of successive accumulation, analogous to those so common in ordinary subaqueous deposits. As the latter formations were found divisible into natural groups, characterized by certain peculiarities of mineral composition, so also were the primitive. In the next place, there were discovered, in many districts, certain members of the so-called primitive series, either alternating with, or passing by intermediate gradations into rocks of a decidedly mechanical origin, containing traces of organic remains. From such gradual passage the aqueous origin of the stratified crystalline rocks was fairly inferred; and as we find in the different strata of subaqueous origin every gradation between a mechanical and a purely crystalline texture; between sand, for example, and saccharoid gypsum, the latter having, probably, been precipitated originally in a crystalline form, from water containing sulphate of lime in solution, so it was imagined that, in a

former condition of the planet, the different degrees of crystallization in the older rocks might have been dependent on the varying state of the menstruum from which they were precipitated.

The presence of certain crystalline ingredients in the composition of many of the primary rocks, rendered it necessary to resort to many arbitrary hypotheses, in order to explain their precipitation from aqueous solution, and for this reason a difference in the condition of the planet, and of the pristine energy of chemical causes, was assumed. A train of speculation originally suggested by the observed effects of aqueous agents, was thus pushed beyond the limits of analogy, and it was not until a different and almost opposite course of induction was pursued, beginning with an examination of volcanic products, that more sound theoretical views were established.

Granite of igneous origin. As we are merely desirous, in this chapter, of fixing in the reader's mind the leading divisions of the rocks composing the earth's crust, we cannot enter, at present, into a detailed account of these researches, but shall only observe, that a passage was first traced from lava into other more crystalline igneous rocks, and from these again to granite, which last was found to send forth dikes and veins into the contiguous strata in a manner strictly analogous to that observed in volcanic rocks, and producing at the point of contact such changes as might be expected to result from the influence of a heated mass cooling down slowly under great pressure from a state of fusion. The want of stratification in granite supplied another point of analogy in confirmation of its igneous origin; and as some masses were found to send out veins through others, it was evident that there were granites of different ages, and that instead of forming in all cases the oldest part of the earth's crust, as had at first been supposed, the granites were often of comparatively recent origin, sometimes newer than the stratified rocks which covered them.

Stratified primary rocks. The theory of the origin of the other crystalline rocks was soon modified by these new views

respecting the nature of granite. First it was shown, by numerous examples, that ordinary volcanic dikes might produce great alterations in the sedimentary strata which they traversed, causing them to assume a more crystalline texture, and obliterating all traces of organic remains, without, at the same time, destroying either the lines of stratification, or even those which mark the division into laminæ. It was also found, that granite dikes and veins produced analogous, though somewhat different changes; and hence it was suggested as highly probable, that the effects to which small veins gave rise, to the distance of a few yards, might be superinduced on a much grander scale where immense masses of fused rock, intensely heated for ages, came in contact at great depths from the surface with sedimentary formations. The slow action of heat in such cases, it was thought, might occasion a state of semi-fusion, so that, on the cooling down of the masses, the different materials might be re-arranged in new forms, according to their chemical affinities, and all traces of organic remains might disappear, while the stratiform and lamellar texture remained.

May be of different ages. According to these views, the primary strata may have assumed their crystalline structure at as many successive periods as there have been distinct eras of the formation of granite, and their difference of mineral composition may be attributed, not to an original difference of the conditions under which they were deposited at the surface, but to subsequent modifications superinduced by heat at great depths below the surface.

The strict propriety of the term primitive, as applied to granite and to the granitiform and associated rocks, thus became questionable, and the term primary was very generally substituted, as simply expressing the fact, that the crystalline rocks, as a mass, were older than the *secondary*, or those which are unequivocally of a mechanical origin and contain organic remains.

Transition formations. The reader may readily conceive, even from the hasty sketch which we have thus given of the supposed origin of the stratified primary rocks, that they may

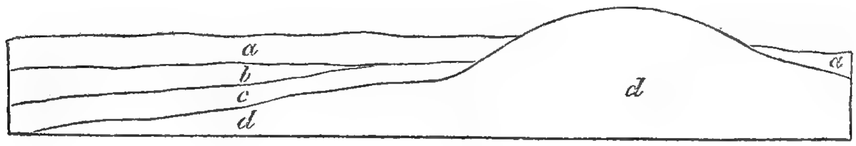
occasionally graduate into the secondary; accordingly, an attempt was made, when the classification of rocks was chiefly derived from mineral structure, to institute an order called *transition*, the characters of which were intermediate between those of the primary and secondary formations. Some of the shales, for example, associated with these strata, often passed insensibly into clay slates, undistinguishable from those of the granitic series; and it was often difficult to determine whether some of the compound rocks of this transition series, called greywacke, were of mechanical or chemical origin. The imbedded organic remains were rare, and sometimes nearly obliterated; but by their aid the groups first called transition were at length identified with rocks, in other countries, which had undergone much less alteration, and wherein shells and zoophytes were abundant.

The term transition, however, was still retained, although no longer applicable in its original signification. It was now made to depend on the identity of certain species of organized fossils; yet reliance on mineral peculiarities was not fairly abandoned, as constituting part of the characters of the group. This circumstance became a fertile source of ambiguity and confusion; for although the species of the transition strata denoted a certain epoch, the intermediate state of mineral character gave no such indications, and ought never to have been made the basis of a chronological division of rocks.

Order of succession of stratified masses. All the subaqueous strata which we before alluded to as overlying the primary, were at first called secondary; and when they had been found divisible into different groups, characterised by certain organic remains and mineral peculiarities, the relative position of these groups became a matter of high interest. It was soon found that the order of succession was never inverted, although the different formations were not coextensively distributed; so that, if there be four different formations, as *a*, *b*, *c*, *d*, in the annexed diagram (No. 1), which, in certain localities, may be seen in vertical superposition, the uppermost or newest of them,

a, will in other places be in contact with *c*, or with the lowest

No. 1.



of the whole series, *d*, all the intermediate formations being absent.

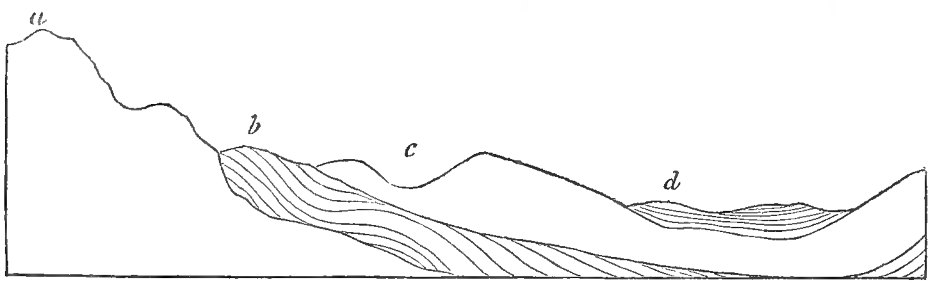
Tertiary formations. After some progress had been made in classifying the secondary rocks, and in assigning to each its relative place in a chronological series, another division of sedimentary formations was established, called *tertiary*, as being of newer origin than the secondary. The fossil contents of the deposits belonging to this newly-instituted order are, upon the whole, very dissimilar from those of the secondary rocks, not only all the species, but many of the most remarkable animal and vegetable forms, being distinct. The tertiary formations were also found to consist very generally of detached and isolated masses, surrounded on all sides by primary and secondary rocks, and occupying a position, in reference to the latter, very like that of the waters of lakes, inland seas, and gulfs, in relation to a continent, and, like such waters, being often of great depth, though of limited area. The imbedded organic remains were chiefly those of marine animals, but with frequent intermixtures of terrestrial and freshwater species so rarely found among the secondary fossils. Frequently there was evidence of the deposits having been purely lacustrine, a circumstance which has never yet been clearly ascertained in regard to any secondary group.

We shall consider more particularly, in the next chapter, how far this distinction of rocks into secondary and tertiary is founded in nature, and in what relation these two orders of mineral masses may be supposed to stand to each other. But before we offer any general views of this kind, it may be useful to present the reader with a succinct sketch of the principal

points in the history of the discovery and classification of the tertiary strata.

Paris Basin. The first series of deposits belonging to this class, of which the characters were accurately determined, were those which occur in the neighbourhood of Paris, first described by MM. Cuvier and Brongniart*. They were ascertained to fill a depression in the chalk (as the beds *d*, in diagram No. 2, rest upon *c*), and to be composed of different materials, some-

No. 2.



a, Primary rocks.
b, Older secondary formations. *c*, Chalk.
d, Tertiary formation.

times including the remains of marine animals, and sometimes of freshwater. By the aid of these fossils, several distinct alternations of marine and freshwater formations were clearly shown to lie superimposed upon each other, and various speculations were hazarded respecting the manner in which the sea had successively abandoned and regained possession of tracts which had been occupied in the intervals by the waters of rivers or lakes. In one of the subordinate members of this Parisian series, a great number of scattered bones and skeletons of land animals were found entombed, the species being perfectly dissimilar from any known to exist, as indeed were those of almost all the animals and plants of which any portions were discovered in the associated deposits.

We shall defer, to another part of this work, a more detailed account of this interesting formation, and shall merely observe in this place, that the investigation of the fossil contents of these beds forms an era in the progress of the science. The

* Environs de Paris, 1811.

French naturalists brought to bear upon their geological researches so much skill and proficiency in comparative anatomy and conchology, as to place in a strong light the importance of the study of organic remains, and the comparatively subordinate interest attached to the mere investigation of the structure and mineral ingredients of rocks.

A variety of tertiary formations were soon afterwards found in other parts of Europe, as in the south-east of England, in Italy, Austria, and different parts of France, especially in the basins of the Loire and Gironde, all strongly contrasted to the secondary rocks. As in the latter class many different divisions had been observed to preserve the same mineral characters and organic remains over wide areas, it was natural that an attempt should first be made to trace the different subdivisions of the Parisian tertiary strata throughout Europe, for some of these were not inferior in thickness to several of the secondary formations that had a wide range.

But in this case the analogy, however probable, was not found to hold good, and the error, though almost unavoidable, retarded seriously the progress of geology. For as often as a new tertiary group was discovered, as that of Italy, for example, an attempt was invariably made, in the first instance, to discover in what characters it agreed with some one or more subordinate members of the Parisian type. Every fancied point of correspondence was magnified into undue importance, and such trifling circumstances, as the colour of a bed of sand or clay, were dwelt upon as proofs of identification, while the difference in the mineral character and organic contents of the group from the whole Parisian series was slurred over and thrown into the shade.

By the influence of this illusion, the succession and chronological relations of different tertiary groups were kept out of sight. The difficulty of clearly discerning these, arose from the frequent isolation of the position of the tertiary formations before described, since, a proportion as the areas occupied by them are limited, it is rare to discover a place where one

set of strata overlap another, in such a manner that the geologist might be enabled to determine the difference of age by direct superposition.

ORIGIN OF THE EUROPEAN TERTIARY STRATA AT SUCCESSIVE PERIODS.

We shall now very briefly enumerate some of the principal steps which eventually led to a conviction of the necessity of referring the European tertiary formations to distinct periods, and the leading data by which such a chronological series may be established.

London and Hampshire Basins.—Very soon after the investigation, before alluded to, of the Parisian strata, those of Hampshire and of the basin of the Thames were examined in our own country. Mr. Webster found these English tertiary deposits to repose, like those in France, upon the chalk or newest rock of the secondary series. He identified a great variety of the shells occurring in the British and Parisian strata, and ascertained that, in the Isle of Wight, an alternation of marine and freshwater beds occurred, very analogous to that observed in the basin of the Seine*. But no two sets of strata could well be more dissimilar in mineral composition, and they were only recognized to belong to the same era, by aid of the specific identity of their organic remains. The discordance, in other respects, was as complete as could well be imagined, for the principal marine formation in the one country consisted of blue clay, in the other of white limestone, and a variety of curious rocks in the neighbourhood of Paris, had no representatives whatever in the south of England.

Subapennine Beds.—The next important discovery of tertiary strata was in Italy, where Brocchi traced them along the flanks of the Apennines, from one extremity of the peninsula to the other, usually forming a lower range of hills, called by him the Subapennines†. These formations, it is true, had

* Webster in Englefield's Isle of Wight and Geol. Trans., vol. ii. p. 161.

† Conch. Foss. Subap., 1814.

been pointed out by the older Italian writers, and some correct ideas, as we have seen, had been entertained respecting their recent origin, as compared to the inclined secondary rocks on which they rested*. But accurate data were now for the first time collected, for instituting a comparison between them and other members of the great European series of tertiary formations.

Brocchi came to the conclusion that nearly one-half of several hundred species of fossil shells procured by him from these Subapennine beds were identical with those now living in existing seas, an observation which did not hold true in respect to the organic remains of the Paris basin. It might have been supposed that this important point of discrepancy would at once have engendered great doubt as to the identity, in age, of any part of the Subapennine beds to any one member of the Parisian series; but, for reasons above alluded to, this objection was not thought of much weight, and it was supposed that a group of strata, called 'the upper marine formation,' in the basin of the Seine, might be represented by all the Subapennine clays and yellow sand.

English Crag.—Several years before, an English naturalist, Mr. Parkinson, had observed, that certain shelly strata, in Suffolk, which overlaid the blue clay of London, contained distinct fossil species of testacea, and that a considerable portion of these might be identified with species now inhabiting the neighbouring sea†. These overlying beds, which were provincially termed 'Crag,' were of small thickness, and were not regarded as of much geological importance. But when duly considered, they presented a fact worthy of great attention, viz., the superposition of a tertiary group, inclosing, like the Subapennine beds, a great intermixture of recent species of shells, upon beds wherein a very few remains of recent or living species were entombed.

Mr. Conybeare, in his excellent classification of the English

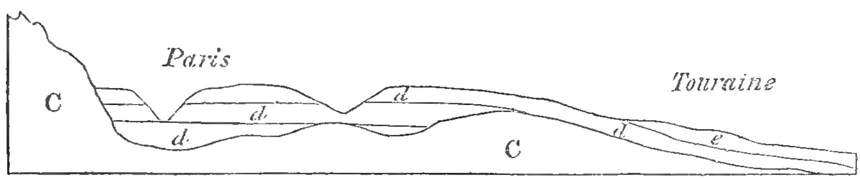
* See vol. i. p. 51, for opinions of Odoardi, in 1761.

† Geol. Trans., vol. i. p. 324. 1811.

strata*, placed the crag as the uppermost of the British series, and several geologists began soon to entertain an opinion that this newest of our tertiary formations might correspond in age to the Italian strata described by Brocchi.

Tertiary Strata of Touraine.—The next step towards establishing a succession of tertiary periods was the evidence adduced to prove that certain formations, more recent than the uppermost members of the Parisian series, were also older than the Subapennine beds, so that they constituted deposits of an age intermediate between the two types above alluded to. M. Desnoyers, for example, ascertained that a group of marine strata in Touraine, in the basin of the Loire (*e*, diagram No. 3), rest upon the uppermost subdivision of the

No. 3.



C, Chalk and other secondary formations.
d, Tertiary formation of Paris basin.
e, Superimposed marine tertiary beds of the Loire.

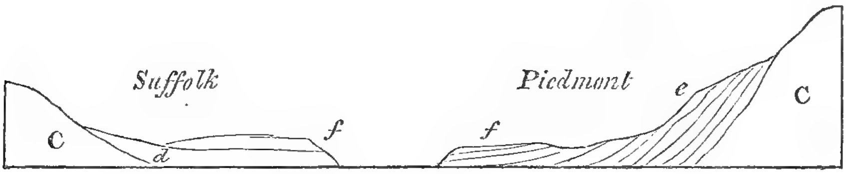
Parisian group *d*, which consists of a lacustrine formation, extending continuously throughout a platform which intervenes between the basin of the Seine and that of the Loire. These overlying marine strata, M. Desnoyers assimilated to the English crag, to which they bear some analogy, although their organic remains differ considerably, as will be afterwards shown.

A large tertiary deposit had already been observed in the south-west of France, around Bordeaux and Dax, and a description of its fossils had been published by M. de Basterot†. Many of the species were peculiar, and differed from those of the strata now called Subapennine; yet these same peculiar and characteristic fossils reappeared in Piedmont, in a series of

* Outlines of the Geology of England and Wales, 1822.
† Mem. de la Soc. d'Hist. Nat. de Paris, tome ii., 1825.

strata inferior in position to the Subapennines (as *e* underlies *f*, diagram No. 4).

No. 4.



C, Chalk and older formations.
d, London clay (older tertiary).
e, Tertiary strata of same age as beds of the Loire.
f, Crag and Subapennine tertiary deposits.

This inferior group, *e*, composed principally of green sand, occurs in the hills of Mont Ferrat, and beds of the same age are seen in the valley of the Bormida. They also form the hill of the Superga, near Turin, where M. Bonelli formed a large collection of their fossils, and identified them with those discovered near Bordeaux and in the basin of the Gironde.

But we are indebted to M. Deshayes for having proved, by a careful comparison of the entire assemblage of shells found in the above-mentioned localities, in Touraine, in the south-east of France, and in Piedmont, that the whole of these three groups possess the same zoological characters, and belong to the same epoch, as also do the shells described by M. Constant Prevost, as occurring in the basin of Vienna*.

Now the reader will perceive, by reference to the observations above made, and to the accompanying diagrams, that one of the formations of this intervening period, *e*, has been found superimposed upon the highest member of the Parisian series, *d*; while another of the same set has been observed to underlie the Subapennine beds, *f*. Thus the chronological series, *d*, *e*, *f*, is made out, in which the deposits, originally called tertiary, those of the Paris and London basins, for example, occupy the lowest position, and the beds called 'the Crag,' and 'the Subapennines,' the highest.

Tertiary Strata newer than the Subapennine.—The fossil

* Sur la Constitution, &c. du bassin de Vienne, Journ. de Phys., Nov. 1820.

remains which characterize each of the three successive periods above alluded to, approximate more nearly to the assemblage of *species* now existing, in proportion as their origin is less remote from our own era, or, in other words, the recent species are always more numerous, and the extinct more rare, in proportion to the low antiquity of the formation. But the discordance between the state of the organic world indicated by the fossils of the Subapennine beds and the actual state of things is still considerable, and we naturally ask, are there no monuments of an intervening period?—no evidences of a gradual passage from one condition of the animate creation to that which now prevails, and which differs so widely?

It will appear in the sequel, that such monuments are not wanting, and that there are marine strata entering into the composition of extensive districts, and of hills of no trifling height, which contain the exuviæ of testacea and zoophytes, hardly distinguishable, as a group, from those now peopling the neighbouring seas. Thus the line of demarcation between the actual period and that immediately antecedent, is quite evanescent, and the newest members of the tertiary series will be often found to blend with the formations of the historical era.

In Europe, these modern strata have been found in the district around Naples, in the territory of Otranto and Calabria, and more particularly in the island of Sicily; and the bare enumeration of these localities cannot fail to remind the reader, that they belong to regions where the volcano and the earthquake are now active, and where we might have anticipated the discovery of emphatic proofs, that the conversion of sea into land had been of frequent occurrence at very modern periods.

CHAPTER III.

Different circumstances under which the secondary and tertiary formations may have originated—Secondary series formed when the ocean prevailed: Tertiary during the conversion of sea into land, and the growth of a continent—Origin of interruption in the sequence of formations—The areas where new deposits take place are always varying—Causes which occasion this transference of the places of sedimentary deposition—Denudation augments the discordance in age of rocks in contact—Unconformability of overlying formations—In what manner the shifting of the areas of sedimentary deposition may combine with the gradual extinction and introduction of species to produce a series of deposits having distinct mineral and organic characters.

DIFFERENT CIRCUMSTANCES UNDER WHICH THE SECONDARY AND TERTIARY FORMATIONS MAY HAVE ORIGINATED.

We have already glanced at the origin of some of the principal points of difference in the characters of the primary and secondary rocks, and may now briefly consider the relation in which the secondary stand to the tertiary, and the causes of that succession of tertiary formations described in the last chapter.

It is evident that large parts of Europe were simultaneously submerged beneath the sea when different portions of the secondary series were formed, because we find homogeneous mineral masses, including the remains of marine animals, referrible to the secondary period, extending over great areas; whereas the detached and isolated position of tertiary groups, in basin or depressions bounded by secondary and primary rocks, favours the hypothesis of a sea interrupted by extensive tracts of dry land.

State of the Surface when the Secondary Strata were formed.

Let us consider the changes that must be expected to accompany the gradual conversion of part of the bed of an ocean into a continent, and the different characters that might be imparted

to subaqueous deposits formed during the period when the sea prevailed, as contrasted with those that might belong to the subsequent epoch when the land should predominate. First, we may suppose a vast submarine region, such as the bed of the western Atlantic, to receive for ages the turbid waters of several great rivers, like the Amazon, Orinoco, or Mississippi, each draining a considerable continent. The sediment thus introduced might be characterized by a peculiar colour and composition, and the same homogeneous mixture might be spread out over an immense area by the action of a powerful current, like the Gulf-stream. First one submarine basin, and then another, might be filled, or rendered shallow, by the influx of transported matter, the same species of animals and plants still continuing to inhabit the sea, so that the organic, as well as the mineral characters, might be constant throughout the whole series of deposits.

In another part of the same ocean, let us suppose masses of coralline and shelly limestone to grow, like those of the Pacific, simultaneously over a space several thousand miles in length, and thirty or forty degrees of latitude in breadth, while volcanic eruptions give rise, at different intervals, to igneous rocks, having a common subaqueous character in different parts of the vast area.

It is evident that, during such a state of a certain quarter of the globe, beds of limestone and other rocks might be formed, and retain a common character over spaces equal to a large portion of Europe.

State of the Surface when the Tertiary Groups were formed.

But when the area under consideration began to be converted into land, a very different condition of things would succeed. A series of subterranean movements might first give rise to small rocks and isles, and then, by subsequent elevations, to larger islands, by the junction of the former. These lands would consist partly of the mineral masses before described, whether coralline, sedimentary, or volcanic, and partly

of the subjacent rocks, whatever they may have been, which constituted the original bed of the ocean. Now the degradation of these lands would commence immediately upon their emergence, the waves of the sea undermining the cliffs, and torrents flowing from the surface, so that new strata would begin to form in different places; and in proportion as the lands increased, these deposits would augment.

At length by the continued rising and sinking of different parts of the bed of the ocean, a number of distinct basins would be formed, wherein different kinds of sediment, each distinguished by some local character, might accumulate. Some of the groups of isles that had first risen would, in the course of ages, become the central mountain ranges of continents, and different lofty chains might thus be characterized by similar rocks of contemporaneous origin, the component strata having originated under analogous circumstances in the ocean before described.

Finally, when large tracts of land existed, there would be a variety of disconnected gulfs, inland seas, and lakes, each receiving the drainage of distinct hydrographical basins, and becoming the receptacles of strata distinguished by marked peculiarities of mineral composition. The organic remains would also be more varied, for in one locality freshwater species would be imbedded, as in deposits now forming in the lakes of Switzerland and the north of Italy; in another, marine species, as in the Aral and Caspian; in a third region, gulfs of brackish water would be converted into land, like those of Bothnia and Finland in the Baltic; in a fourth, there might be great fluviatile and marine formations along the borders of a chain of inland seas, like the deltas now growing at the mouths of the Don, Danube, Nile, Po, and Rhone, along the shores of the Azof, Euxine, and Mediterranean. These deposits would each partake more or less of the peculiar mineral character of adjoining lands, the degradation of which would supply sediment to the different rivers.

Now if such be, in a great measure, the distinction between

the circumstances under which the secondary and tertiary series originated, it is quite natural that particular tertiary groups should occupy areas of comparatively small extent,—that they should frequently consist of littoral and lacustrine deposits, and that they should often contain those admixtures of terrestrial, freshwater, and marine remains, which are so rare in secondary rocks. It might also be expected, that the tertiary volcanic formations should be much less exclusively submarine, and this we accordingly find to be the case.

CAUSES OF THE SUPERPOSITION OF SUCCESSIVE FORMATIONS HAVING DISTINCT MINERAL AND ORGANIC CHARACTERS.

But we have still to account for those remarkable breaks in the series of superimposed formations, which are common both to the secondary and tertiary rocks, but are more particularly frequent in the latter.

The elucidation of this curious point is the more important, because geologists of a certain school appeal to phenomena of this kind in support of their doctrine of great catastrophes, out of the ordinary course of nature, and sudden revolutions of the globe.

It is only by carefully considering the combined action of all the causes of change now in operation, whether in the animate or inanimate world, that we can hope to explain such complicated appearances as are exhibited in the general arrangement of mineral masses. In attempting, therefore, to trace the origin of these violations of continuity, we must re-consider many of the topics treated of in our two former volumes, such as the effects of the various agents of decay and reproduction, the imbedding of organic remains, and the extinction of species.

Shifting of the Areas of Sedimentary Deposition.—By reverting to our survey of the destroying and renovating agents, it will be seen that the surface of the terraqueous globe may be divided into two parts, one of which is undergoing repair, while the other, constituting, at any one period, by far the

largest portion of the whole, is either suffering degradation, or remaining stationary without loss or increment. The reader will assent at once to this proposition, when he reflects that the dry land is, for the most part, wasting by the action of rain, rivers, and torrents, while the effects of vegetation have, as we have shown, only a conservative tendency, being very rarely instrumental in adding new masses of mineral matter to the surface of emerged lands; and when he also reflects that part of the bed of the sea is exposed to the excavating action of currents, while the greater part, remote from continents and islands, probably receives no new deposits whatever, being covered for ages with the clear blue waters uncharged with sediment. Here the relics of organic beings, lying in the ooze of the deep, may decompose like the leaves of the forest in autumn, and leave no wreck behind, but merely supply nourishment, by their decomposition, to succeeding races of marine animals and plants.

The other part of the terraqueous surface is the receptacle of new deposits, and in this portion alone, as we pointed out in the last volume, the remains of animals and plants become fossilized. Now the position of this area, where new formations are in progress, and where alone any memorials of the state of organic life are preserved, is always varying, and must for ever continue to vary; and, for the same reason, that portion of the terraqueous globe which is undergoing waste, also shifts its position, and these fluctuations depend partly on the action of aqueous, and partly of igneous causes.

In illustration of these positions we may observe, that the sediment of the Rhone, which is thrown into the lake of Geneva, is now conveyed to a spot a mile and a half distant from that where it accumulated in the tenth century, and six miles from the point where the delta began originally to form. We may look forward to the period when the lake will be filled up, and then a sudden change will take place in the distribution of the transported matter; for the mud and sand brought down from the Alps will thenceforth, instead of being deposited

near Geneva, be carried nearly two hundred miles southwards, where the Rhone enters the Mediterranean.

The additional matter thus borne down to the lower delta of the Rhone would not only accelerate its increase, but might affect the mineral character of the strata there deposited, and thus give rise to an upper group, or subdivision of beds, having a distinct character. But the filling up of a lake, and the consequent transfer of the sediment to a new place, may sometimes give rise to a more abrupt transition from one group to another; as, for example, in a gulf like that of the St. Lawrence, where no deposits are now accumulated, the river being purged of all its impurities in its previous course through the Canadian lakes. Should the lowermost of these lakes be at any time filled up with sediment, or laid dry by earthquakes, the waters of the river would thenceforth become turbid, and strata would begin to be deposited in the gulf, where a new formation would immediately overlie the ancient rocks now constituting the bottom. In this case there would be an abrupt passage from the inferior and more ancient, to the newer superimposed formation.

The same sudden coming on of new sedimentary deposits, or the suspension of those which were in progress, must frequently occur in different submarine basins where there are currents which are always liable, in the course of ages, to change their direction. Suppose, for instance, a sea to be filling up in the same manner as the Adriatic, by the influx of the Po, Adige, and other rivers. The deltas, after advancing and converging, may at last come within the action of a transverse current, which may arrest the further deposition of matter, and sweep it away to a distant point. Such a current now appears to prey upon the delta of the Nile, and to carry eastward the annual accessions of sediment that once added rapidly to the plains of Egypt.

On the other hand, if a current charged with sediment vary its course, a circumstance which, as we have shown, must happen to all of them in the lapse of ages, the accumulation of

transported matter will at once cease in one region, and commence in another.

Although the causes which occasion the transference of the places of sedimentary deposition are continually in action in every region, yet they are most frequent where subterranean movements alter, from time to time, the levels of land, and they must be immense during the successive elevations and depressions which must be supposed to accompany the rise of a great continent from the deep. A trifling change of level may sometimes throw a current into a new direction, or alter the course of a considerable river. Some tracts will be alternately submerged and laid dry by subterranean movements; in one place a shoal will be formed, whereby the waters will drift matter over spaces where they once threw down their burden, and new cavities will elsewhere be produced, both marine and lacustrine, which will intercept the waters bearing sediment, and thereby stop the supply once carried to some distant basin.

We have before stated, that a few earthquakes of moderate power might cause a subsidence which would connect the sea of Azof with a large part of Asia now below the level of the ocean. This vast depression, recently shown by Humboldt to extend over an area of eighteen thousand square leagues, surrounds Lake Aral and the Caspian, on the shores of which seas it sinks in some parts to the depth of three hundred feet below the level of the ocean. The whole area might thus suddenly become the receptacle of new beds of sand and shells, probably differing in mineral character from the masses previously existing in that country, for an exact correspondence could only arise from a precise identity in the whole combination of circumstances which should give rise to formations produced at different periods in the same place.

Without entering into more detailed explanations, the reader will perceive that, according to the laws now governing the aqueous and igneous causes, distinct deposits must, at different periods, be thrown down on various parts of the earth's surface,

and that, in the course of ages the same area may become, again and again, the receptacle of such dissimilar sets of strata. During intervening periods, the space may either remain unaltered, or suffer what is termed *denudation,* in which case a superior set of strata are removed by the power of running water, and subjacent beds are laid bare, as happens wherever a sea encroaches upon a line of coast. By such means, it is obvious that the discordance in age of rocks in contact must often be greatly increased.

The frequent unconformability in the stratification of the inferior and overlying formation is another phenomenon in their arrangement, which may be considered as a natural consequence of those movements that accompany the gradual conversion of part of an ocean into land; for by such convulsions the older set of strata may become rent, shattered, inclined, and contorted to any amount. If the movement entirely cease before a new deposit is formed in the same tract, the superior strata may repose horizontally upon the dislocated series. But even if the subterranean convulsions continue with increasing violence, the more recent formations must remain comparatively undisturbed, because they cannot share in the immense derangement previously produced in the older beds, while the latter, on the contrary, cannot fail to participate in all the movements subsequently communicated to the newer.

Change of Species everywhere in progress.—If, then, it be conceded, that the combined action of the volcanic and the aqueous forces would give rise to a succession of distinct formations, and that these would be sometimes unconformable, let us next inquire in what manner these groups might become characterized by different assemblages of fossil remains.

We endeavoured to show, in the last volume, that the hypothesis of the gradual extinction of certain animals and plants, and the successive introduction of new species, was quite consistent with all that is known of the existing economy of the animate world; and if it be found the only hypothesis which is reconcilable with geological phenomena, we shall have

strong grounds for conceiving that such is the order of nature.

Fossilization of Plants and Animals partial.—We have seen that the causes which limit the duration of species are not confined, at any one time, to a particular part of the globe; and, for the same reason, if we suppose that their place is supplied, from time to time, by new species, we may suppose their introduction to be no less generally in progress. Hence, from all the foregoing premises, it would follow, that the change of species would be in simultaneous operation everywhere throughout the habitable surface of sea and land; whereas the fossilization of plants and animals must always be confined to those areas where new strata are produced. These areas, as we have proved, are always shifting their position, so that the fossilizing process, whereby the commemoration of the particular state of the organic world, at any given time, is effected, may be said to move about, visiting and revisiting different tracts in succession.

In order more distinctly to elucidate our idea of the working of this machinery, let us compare it to a somewhat analogous case that might easily be imagined to occur in the history of human affairs. Let the mortality of the population of a large country represent the successive extinction of species, and the births of new individuals the introduction of new species. While these fluctuations are gradually taking place everywhere, suppose commissioners to be appointed to visit each province of the country in succession, taking an exact account of the number, names, and individual peculiarities of all the inhabitants, and leaving in each district a register containing a record of this information. If, after the completion of one census, another is immediately made after the same plan, and then another, there will, at last, be a series of statistical documents in each province. When these are arranged in chronological order, the contents of those which stand next to each other will differ according to the length of the intervals of time between the taking of each census.

If, for example, all the registers are made in a single year, the proportion of deaths and births will be so small during the interval between the compiling of two consecutive documents, that the individuals described in each will be nearly identical; whereas, if there are sixty provinces, and the survey of each requires a year, there will be an almost entire discordance between the persons enumerated in two consecutive registers.

There are undoubtedly some other causes besides the mere quantity of time which may augment or diminish the amount of discrepancy. Thus, for example, at some periods a pestilential disease may lessen the average duration of human life, or a variety of circumstances may cause the births to be unusually numerous, and the population to multiply; or, a province may be suddenly colonized by persons migrating from surrounding districts.

We must also remind the reader, that we do not propose the above case as an exact parallel to those geological phenomena which we desire to illustrate; for the commissioners are supposed to visit the different provinces in rotation, whereas the commemorating processes by which organic remains become fossilized, although they are always shifting from one area to another, are yet very irregular in their movements. They may abandon and revisit many spaces again and again, before they once approach another district; and besides this source of irregularity, it may often happen, that while the depositing process is suspended, denudation may take place, which may be compared to the occasional destruction of some of the statistical documents before mentioned. It is evident, that where such accidents occur, the want of continuity in the series may become indefinitely great, and that the monuments which follow next in succession will by no means be equidistant from each other in point of time.

If this train of reasoning be admitted, the frequent distinctness of the fossil remains, in formations immediately in contact, would be a necessary consequence of the existing laws of

sedimentary deposition, accompanied by the gradual birth and death of species.

We have already stated, that we should naturally look for a change in the mineral character in strata thrown down at distant intervals in the same place; and, in like manner, we must also expect, for the reason last set forth, to meet occasionally with sudden transitions from one set of organic remains to another. But the causes which have given rise to such differences in mineral characters, have no necessary connexion with those which have produced a change in the species of imbedded plants and animals.

When the lowest of two sets of strata are much dislocated over a wide area, the upper being undisturbed, there is usually a considerable discordance in the organic remains of the two groups; but this coincidence must not be ascribed to the agency of the disturbing forces, as if they had exterminated the living inhabitants of the surface. The immense *lapse of time* required for the development of so great a series of subterranean movements, has in these cases allowed the species also throughout the globe to vary, and hence the two phenomena are usually concomitant.

Although these inferences appear to us very obvious, we are aware that they are directly opposed to many popular theories respecting catastrophes; we shall, therefore, endeavour to place our views in a still clearer light before the reader. Suppose we had discovered two buried cities at the foot of Vesuvius, immediately superimposed upon each other, with a great mass of tuff and lava intervening, just as Portici and Resina, if now covered with ashes, would overlie Herculaneum. An antiquary might possibly be entitled to infer, from the inscriptions on public edifices, that the inhabitants of the inferior and older town were Greeks, and those of the modern, Italians. But he would reason very hastily, if he also concluded from these data, that there had been a sudden change from the Greek to the Italian language in Campania. Suppose he afterwards found *three* buried cities, one above the other, the intermediate

one being Roman, while, as in the former example, the lowest was Greek, and the uppermost Italian, he would then perceive the fallacy of his former opinion, and would begin to suspect that the catastrophes, whereby the cities were inhumed, might have no relation whatever to the fluctuations in the language of the inhabitants; and that, as the Roman tongue had evidently intervened between the Greek and Italian, so many other dialects may have been spoken in succession, and the passage from the Greek to the Italian may have been very gradual, some terms growing obsolete, while others were introduced from time to time.

If this antiquary could have shown that the volcanic paroxysms of Vesuvius were so governed as that cities should be buried one above the other, just as often as any variation occurred in the language of the inhabitants, then, indeed, the abrupt passage from a Greek to a Roman, and from a Roman to an Italian city, would afford proof of fluctuations no less sudden in the language of the people.

So in Geology, if we could assume that it is part of the plan of nature to preserve, in every region of the globe, an unbroken series of monuments to commemorate the vicissitudes of the organic creation, we might infer the sudden extirpation of species, and the simultaneous introduction of others, as often as two formations in contact include dissimilar organic fossils. But we must shut our eyes to the whole economy of the existing causes, aqueous, igneous, and organic, if we fail to perceive *that such is not the plan of Nature.*

CHAPTER IV.

Chronological relations of mineral masses the first object in geological classification—Superposition, proof of more recent origin—Exceptions in regard to volcanic rocks—Relative age proved by included fragments of older rocks—Proofs of contemporaneous origin derived from mineral characters—Variations to which these characters are liable—Recurrence of distinct rocks at successive periods—Proofs of contemporaneous origin derived from organic remains—Zoological provinces are of limited extent, yet spread over wider areas than homogeneous mineral deposits—Different modes whereby dissimilar mineral masses and distinct groups of species may be proved to have been contemporaneous.

DETERMINATION OF THE RELATIVE AGES OF ROCKS.

In attempting to classify the mineral masses which compose the crust of the earth, the principal object which the geologist must keep in view, is to determine with accuracy their chronological relations, for it is abundantly clear, that different rocks have been formed in succession; and in order thoroughly to comprehend the manner in which they enter into the structure of our continents, we should study them with reference to the time and mode of their formation.

We shall now, therefore, consider by what characters the relative ages of different rocks may be established, whereby we may be supplied at once with sound information of the greatest practical utility, and which may throw, at the same time, the fullest light on the ancient history of the globe.

Proofs of relative age by superposition.

It is evident that where we find a series of horizontal strata, of sedimentary origin, the uppermost bed must be older than those which it overlies, and that when we observe one distinct set of strata reposing upon another, the inferior is the older of the two. In countries where the original position of mineral

masses has been disturbed, at different periods, by convulsions of extraordinary violence, as in the Alps and other mountainous districts, there are instances where the original position of strata has been reversed; but such exceptions are rare, and are usually on a small scale, and an experienced observer can generally ascertain the true relations of the rocks in question, by examining some adjoining districts where the derangement has been less extensive.

In regard to volcanic formations, if we find a stratum of tuff or ejected matter, or a stream of lava covering sedimentary strata, we may infer, with confidence, that the igneous rock is the more recent; but, on the other hand, the superposition of aqueous deposits to a volcanic mass does not always prove the former to be of newer origin. If, indeed, we discover strata of tuff with imbedded shells, or, as in the Vicentine and other places, rolled blocks of lava with adhering shells and corals, we may then be sure that these masses of volcanic origin covered the bottom of the sea, before the superincumbent strata were thrown down. But as lava rises from below, and does not always reach the surface, it may sometimes penetrate a certain number of strata, and then cool down, so as to constitute a solid mass of newer origin, although inferior in position. It is, for the most part, by the passage of veins proceeding from such igneous rocks through contiguous sedimentary strata, or by such hardening and other alteration of the overlying bed, as might be expected to result from contact with a heated mass, that we are enabled to decide whether the volcanic matter was previously consolidated, or subsequently introduced.

Proofs by included fragments of older rocks.

A geologist is sometimes at a loss, after investigating a district composed of two distinct formations, to determine the relative ages of each, from want of sections exhibiting their superposition. In such cases, another kind of evidence, of a character no less conclusive, can sometimes be obtained. One group of strata has frequently been derived from the degrada-

tion of another in the immediate neighbourhood, and may be observed to include within it fragments of such older rocks. Thus, for example, we may find chalk with flints, and in another part of the same country, a distinct series, consisting of alternations of clay, sand, and pebbles. If some of these pebbles consist of flints, with silicified fossil shells of the same species as those in the chalk, we may confidently infer, that the chalk is the oldest of the two formations.

We remarked in the second chapter, that some granite must have existed before the most ancient of our secondary rocks, because some of the latter contain rounded pebbles of granite. But for the existence of such evidence, we might not have felt assured that all the granite which we see had not been protruded from below in a state of fusion, subsequently to the origin of the secondary strata.

Proofs of contemporaneous origin derived from mineral characters.

When we have established the relative age of two formations in a given place, by direct superposition, or by other evidence, a far more difficult task remains, to trace the continuity of the same formation, or, in other cases, to find means of referring detached groups of rocks to a contemporaneous origin. Such identifications in age are chiefly derivable from two sources—mineral character and organic contents; but the utmost skill and caution are required in the application of such tests, for scarcely any general rules can be laid down respecting either, that do not admit of important exceptions.

If, at certain periods of the past, rocks of peculiar mineral composition had been precipitated simultaneously upon the floor of an 'universal ocean,' so as to invest the whole earth in a succession of concentric coats, the determination of relative dates in geology might have been a matter of the greatest simplicity. To explain, indeed, the phenomenon would have been difficult, or rather impossible, as such appearances would have implied a former state of the globe, without any analogy

to that now prevailing. Suppose, for example, there were three masses extending over every continent,—the upper of chalk and chloritic sand; the next below, of blue argillaceous limestone; and the third and lowest, of red marl and sandstone; we must imagine that all the rivers and currents of the world had been charged, at the first period, with red mud and sand; at the second, with blue calcareo-argillaceous mud; and at a subsequent epoch, with chalky sediment and chloritic sand.

But if the ocean were universal, there could have been no land to waste away by the action of the sea and rivers, and, therefore, no known source whence the homogeneous sedimentary matter could have been derived. Few, perhaps, of the earlier geologists went so far as to believe implicitly in such universality of formations, but they inclined to an opinion, that they were continuous over areas almost indefinite; and since such a disposition of mineral masses would, if true, have been the least complex and most convenient for the purposes of classification, it is probable that a belief in its reality was often promoted by the hope that it might prove true. As to the objection, that such an arrangement of mineral masses could never result from any combination of causes now in action, it never weighed with the earlier cultivators of the science, since they indulged no expectation of being ever able to account for geological phenomena by reference to the known economy of nature. On the contrary, they set out, as we have already seen, with the assumption that the past and present conditions of the planet were too dissimilar to admit of exact comparison.

But if we inquire into the true composition of any stratum, or set of strata, and endeavour to pursue these continuously through a country, we often find that the character of the mass changes gradually, and becomes at length so different, that we should never have suspected its identity, if we had not been enabled to trace its passage from one form to another.

We soon discover that rocks dissimilar in mineral composition have originated simultaneously; we find, moreover, evidence in certain districts, of the recurrence of rocks of pre-

cisely the same mineral character at very different periods; as, for example, two formations of red sandstone, with a great series of other strata intervening between them. Such repetitions might have been anticipated, since these red sandstones are produced by the decomposition of granite, gneiss, and mica-schist; and districts composed exclusively of these, must again and again be exposed to decomposition, and to the erosive action of running water.

But notwithstanding the variations before alluded to in the composition of one continuous set of strata, many rocks retain the same homogeneous structure and composition, throughout considerable areas, and frequently, after a change of mineral character, preserve their new peculiarities throughout another tract of great extent. Thus, for example, we may trace a limestone for a hundred miles, and then observe that it becomes more arenaceous, until it finally passes into sand or sandstone. We may then follow the last-mentioned formation throughout another district as extensive as that occupied by the limestone first examined.

Proofs of contemporaneous origin derived from organic remains.

We devoted several chapters, in the last volume, to show that the habitable surface of the sea and land may be divided into a considerable number of distinct provinces, each peopled by a peculiar assemblage of animals and plants, and we endeavoured to point out the origin of these separate divisions It was shown that climate is only one of many causes on which they depend, and that difference of longitude, as well as latitude, is generally accompanied by a dissimilarity of indigenous species of organic beings.

As different seas, therefore, and lakes are inhabited at the same period, by different species of aquatic animals and plants, and as the lands adjoining these may be peopled by distinct terrestrial species, it follows that distinct organic remains are imbedded in contemporaneous deposits. If it were otherwise

—if the same species abounded in every climate, or even in every part of the globe where a corresponding temperature, and other conditions favourable to their existence were found, the identification of mineral masses of the same age, by means of their included organic contents, would be a matter of much greater facility.

But, fortunately, the extent of the same zoological provinces, especially those of marine animals, is very great, so that we are entitled to expect, from analogy, that the identity of fossil species, throughout large areas, will often enable us to connect together a great variety of detached and dissimilar formations.

Thus, for example, it will be seen, by reference to our first volume, that deposits now forming in different parts of the Mediterranean, as in the deltas of the Rhone and the Nile, are distinct in mineral composition; for calcareous rocks are precipitated from the waters of the former river, while pebbles are carried into its delta, and there cemented, by carbonate of lime, into a conglomerate; whereas strata of soft mud and fine sand, are formed exclusively in the Nilotic delta. The Po, again, carries down fine sand and mud into the Adriatic; but since this sediment is derived from the degradation of a different assemblage of mountains from those drained by the Rhone or the Nile, we may safely assume that there will never be an exact identity in their respective deposits.

If we pass to another quarter of the Mediterranean, as, for example, to the sea on the coast of Campania, or near the base of Etna in Sicily, or to the Grecian archipelago, we find in all these localities that distinct combinations of rocks are in progress. Occasional showers of volcanic ashes are falling into the sea, and streams of lava are flowing along its bottom; and in the intervals between volcanic eruptions, beds of sand and clay are frequently derived from the waste of cliffs, or the turbid waters of rivers. Limestones, moreover, such as the Italian travertins, are here and there precipitated from the waters of mineral springs, while shells and corals accumulate in various localities. Yet the entire Mediterranean, where the

above-mentioned formations are simultaneously in progress, may be considered as one zoological province; for, although certain species of testacea and zoophytes may be very local, and each region may probably have some species peculiar to it, still a considerable number are common to the whole sea. If, therefore, at some future period, the bed of this inland sea should be converted into land, the geologist might be enabled, by reference to organic remains, to prove the contemporaneous origin of various mineral masses throughout a space equal in area to a great portion of Europe. The Black Sea, moreover, is inhabited by so many identical species, that the delta of the Danube and the Don might, by the same evidence, be shown to have originated simultaneously.

Such identity of fossils, we may remark, not only enables us to refer to the same era, distinct rocks widely separated from each other in the horizontal plane, but also others which may be considerably distant in the vertical series. Thus, for example, we may find alternating beds of clay, sand, and lava, two thousand feet in thickness, the whole of which may be proved to belong to the same epoch, by the specific identity of the fossil shells dispersed throughout the whole series. It may be objected, that different species would, during the same zoological period, inhabit the sea at different depths, and that the case above supposed could never occur; but, for reasons explained in the last volume*, we believe that rivers and tidal currents often act upon the banks of littoral shells, so that a sea of great depth may be filled with strata, containing throughout a considerable number of the same fossils.

The reader, however, will perceive, by referring to what we have said of zoological provinces, that they are sometimes separated from each other by very narrow barriers, and for this reason contiguous rocks may be formed at the same time, differing widely both in mineral contents and organic remains. Thus, for example, the testacea, zoophytes, and fish of the Red Sea, may be considered, as a group, to be very distinct from

* Chap. xvii. p. 280.

those inhabiting the adjoining parts of the Mediterranean, although the two seas are only separated by the narrow isthmus of Suez. We shall show, in a subsequent chapter, that calcareous formations have accumulated, on a great scale, in the Red Sea, in modern times, and that fossil shells of existing species are well preserved therein; while we know that, at the mouth of the Nile, large deposits of mud are amassed, including the remains of Mediterranean species. Hence it follows that if, at some future period, the bed of the Red Sea should be laid dry, the geologist might experience great difficulties in endeavouring to ascertain the relative age of these formations, which, although dissimilar both in organic and mineral characters, were of synchronous origin.

There might, perhaps, be no means of clearing up the obscurity of such a question, yet we must not forget that the north-western shores of the Arabian Gulf, the plains of Egypt, and the isthmus of Suez, are all parts of one province of *terrestrial* species. Small streams, therefore, occasional land-floods, and those winds which drift clouds of sand along the deserts, might carry down into the Red Sea the same shells of fluviatile and land testacea, which the Nile is sweeping into its delta, together with some remains of terrestrial plants, whereby the groups of strata, before alluded to, might, notwithstanding the discrepancy of their mineral composition, and *marine* organic fossils, be shown to have belonged to the same epoch.

In like manner, the rivers which descend into the Caribbean Sea and Gulf of Mexico on one side, and into the Pacific on the other, carry down the same fluviatile and terrestrial spoils into seas which are inhabited by different groups of marine species.

But it will much more frequently happen, that the coexistence of *terrestrial* species, of distinct zoological and botanical provinces, will be proved by the specific identity of the *marine* organic remains which inhabited the intervening space. Thus, for example, the distinct terrestrial species of the south of Europe, north of Africa, and north-west of Asia, might all be

shown to have been contemporaneous, if we suppose the rivers flowing from those three countries to carry the remains of different species of the animal and vegetable kingdoms into the Mediterranean.

In like manner, the sea intervening between the northern shores of Australia and the islands of the Indian ocean, contains a great proportion of the same species of corallines and testacea, yet the *land animals and plants* of the two regions are very dissimilar, even the islands nearest to Australia, as Java, New Guinea, and others, being inhabited by a distinct assemblage of terrestrial species. It is well known that there are calcareous rocks, volcanic tuff, and other strata in progress, in different parts of these intermediate seas, wherein marine organic remains might be preserved and associated with the terrestrial fossils above alluded to.

As it frequently happens that the barriers between different provinces of animals and plants are not very strongly marked, especially where they are determined by differences of temperature, there will usually be a passage from one set of species to another, as in a sea extending from the temperate to the tropical zone. In such cases, we may be enabled to prove, by the fossils of intermediate deposits, the connexion between the distinct provinces, since these intervening spaces will be inhabited by many species, common both to the temperate and equatorial seas.

On the other hand, we may be sometimes able, by aid of a peculiar homogeneous deposit, to prove the former coexistence of distinct animals and plants in distant regions. Suppose, for example, that in the course of ages the sediment of a river, like that of the Red River in Louisiana, is dispersed over an area several hundred leagues in length, so as to pass from the tropics into the temperate zone, the fossil remains imbedded in red mud might indicate the different forms which inhabited, at the same period, those remote regions of the earth.

It appears, then, that mineral and organic characters, although often inconstant, may, nevertheless, enable us to establish the

contemporaneous origin of formations in distant countries. As the same species of organic beings usually extend over wider areas than deposits of a homogeneous composition, they are more valuable in geological classification than mineral peculiarities; but it fortunately happens, that where the one criterion fails, we can often avail ourselves of the other. Thus, for example, sedimentary strata are as likely to preserve the same colour and composition in a part of the ocean reaching from the borders of the tropics to the temperate zone, as in any other quarter of the globe; but in such spaces the variation of species is always most considerable.

In regard to the habitations of species, the marine tribes are of more importance than the terrestrial, not only because they are liable to be fossilized in subaqueous deposits in the greatest abundance, but because they have, for the most part, a wider geographical range. Sometimes, however, it may happen, as we have shown, that the remains of species of some one province of terrestrial plants and animals may be carried down into two seas inhabited by distinct marine species; and here again we have an illustration of the principle, that when one means of identification fails, another is often at hand to assist us.

In conclusion, we may observe, that in endeavouring to prove the contemporaneous origin of strata in remote countries by organic remains, we must form our conclusions from a great number of species, since a single species may be enabled to survive vicissitudes in the earth's surface, whereby thousands of others are exterminated. When a change of climate takes place, some may migrate and become denizens of other latitudes, and so abound there, as to characterize strata of a subsequent era. In the last volume we have stated our reasons for inferring that such migrations are never sufficiently general to interfere seriously with geological conclusions, provided we do not found our theories on the occurrence of a small number of fossil species.

CHAPTER V.

Classification of tertiary formations in chronological order—Comparative value of different classes of organic remains—Fossil remains of testacea the most important—Necessity of accurately determining species—Tables of shells by M. Deshayes—Four subdivisions of the Tertiary epoch—Recent formations—Newer Pliocene period—Older Pliocene period—Miocene period—Eocene period—The distinct zoological characters of these periods may not imply sudden changes in the animate creation—The recent strata form a common point of departure in distant regions—Numerical proportion of recent species of shells in different tertiary periods—Mammiferous remains of the successive tertiary eras—Synoptical Table of Recent and Tertiary formations.

CLASSIFICATION OF TERTIARY FORMATIONS IN CHRONOLOGICAL ORDER.

We explained in the last chapter the principles on which the relative ages of different formations may be ascertained, and we found the character to be chiefly derivable from superposition, mineral structure, and organic remains. It is by combining the evidence deducible from all these sources, that we determine the chronological succession of distinct formations, and this principle is well illustrated by the investigation of those European tertiary strata to the discovery of which we have already alluded.

It will be seen, that in proportion as we have extended our inquiries over a larger area, it has become necessary to intercalate new groups of an age intermediate between those first examined, and we have every reason to expect that, as the science advances, new links in the chain will be supplied, and that the passage from one period to another will become less abrupt. We may even hope, without travelling to distant regions,—without even transgressing the limits of western Europe, to render the series far more complete. The fossil shells, for example, of many of the Subalpine formations, on the northern limits of the plain of the Po, have not yet been carefully col-

lected and compared with those of other countries, and we are almost entirely ignorant of many deposits known to exist in Spain and Portugal.

The theoretical views developed in the last chapter, respecting breaks in the sequence of geological monuments, will explain our reasons for anticipating the discovery of intermediate gradations as often as new regions of great extent are explored.

Comparative value of different classes of organic remains.

In the mean time, we must endeavour to make the most systematic arrangement in our power of those formations which are already known, and in attempting to classify these in chronological order, we have already stated that we must chiefly depend on the evidence afforded by their fossil organic contents. In the execution of this task, we have first to consider what class of remains are most useful, for although every kind of fossil animal and plant is interesting, and cannot fail to throw light on the former history of the globe at a certain period, yet those classes of remains which are of rare and casual occurrence, are absolutely of no use for the purposes of general classification. If we have nothing but plants in one assemblage of strata, and the bones of mammalia in another, we can obviously draw no conclusion respecting the number of species of organic beings common to two epochs; or if we have a great variety, both of vertebrated animals and plants, in one series, and only shells in another, we can form no opinion respecting the remoteness or proximity of the two eras. We might, perhaps, draw some conclusions as to relative antiquity, if we could compare each of these monuments to a third; as, for example, if the species of shells should be almost all identical with those now living, while the plants and vertebrated animals were all extinct; for we might then infer that the shelly deposit was the most recent of the two. But in this case it will be seen that the information flows from a direct comparison of the species of corresponding orders of the animal and vegetable kingdoms,—of plants with plants, and shells with shells; the only mode of

making a systematic arrangement by reference to organic remains.

Although the bones of mammalia in the tertiary strata, and those of reptiles in the secondary, afford us instruction of the most interesting kind, yet the species are too few, and confined to too small a number of localities, to be of great importance in characterizing the minor subdivisions of geological formations. Skeleton of fish are by no means frequent in a good state of preservation, and the science of ichthyology must be farther advanced, before we can hope to determine their specific character with sufficient precision. The same may be said of fossil botany, notwithstanding the great progress that has recently been made in that department; and even in regard to zoophytes, which are so much more abundant in a fossil state than any of the classes above enumerated, we are still greatly impeded in our endeavour to classify strata by their aid, in consequence of the smallness of the number of recent species which have been examined in those tropical seas where they occur in the greatest profusion.

Fossil remains of testacea of chief importance. The testacea are by far the most important of all classes of organic beings which have left their spoils in the subaqueous deposits; they are the medals which nature has chiefly selected to record the history of the former changes of the globe. There is scarcely any great series of strata that does not contain some marine or freshwater shells, and these fossils are often found so entire, especially in the tertiary formations, that when disengaged from the matrix, they have all the appearance of having been just procured from the sea. Their colour, indeed, is usually wanting, but the parts whereon specific characters are founded remain unimpaired; and although the animals themselves are gone, yet their form and habits can generally be inferred from the shell which covered them.

The utility of the testacea, in geological classification, is greatly enhanced by the circumstance, that some forms are proper to the sea, others to the land, and others to freshwater.

Rivers scarcely ever fail to carry down into their deltas some land shells, together with species which are at once fluviatile and lacustrine. The Rhone, for example, receives annually, from the Durance, many shells which are drifted down in an entire state from the higher Alps of Dauphiny, and these species, such as *Bulimus montanus*, are carried down into the delta of the Rhone to a climate far different from that of their native habitation. The young hermit crabs may often be seen on the shores of the Mediterranean, near the mouth of the Rhone, inhabiting these univalves, brought down to them from so great a distance*. At the same time that some freshwater and land species are carried into the sea, other individuals of the same become fossil in inland lakes, and by this means we learn what species of freshwater and marine testacea coexisted at particular eras; and from this again we are able to make out the connexion between various plants and mammifers imbedded in those lacustrine deposits, and the testacea which lived in the ocean at the same time.

There are two other characters of the molluscous animals which render them extremely valuable in settling chronological questions in Geology. The first of these is a wide geographical range, and the second (probably a consequence of the former), is the superior duration of species in this class. It is evident that if the habitation of a species be very local, it cannot aid us greatly in establishing the contemporaneous origin of distant groups of strata, in the manner pointed out in the last chapter; and if a wide geographical range be useful in connecting formations far separated in space, the longevity of species is no less serviceable in establishing the relations of strata considerably distant from each other in point of time.

We shall revert in the sequel to the curious fact, that in tracing back these series of tertiary deposits, many of the existing species of testacea accompany us after the disappearance of all the recent mammalia, as well as the fossil remains of living

* M. Marcel de Serres pointed out this fact to me when I visited Montpellier, July, 1828.

species of several other classes. We even find the skeletons of extinct quadrupeds in deposits wherein all the land and fresh-water shells are of recent species*.

Necessity of accurately determining species.—The reader will already perceive that the systematic arrangement of strata, so far as it rests on organic remains, must depend essentially on the accurate determination of *species*, and the geologist must therefore have recourse to the ablest naturalists, who have devoted their lives to the study of certain departments of organic nature. It is scarcely possible that they who are continually employed in laborious investigations in the field, and in ascertaining the relative position and characters of mineral masses, should have leisure to acquire a profound knowledge of fossil osteology, conchology, and other branches; but it is desirable that, in the latter science at least, they should become acquainted with the principles on which the specific characters are determined, and on which the habits of species are inferred from their peculiar forms. When the specimens are in an imperfect state of preservation, or the shells happen to belong to genera in which it is difficult to decide on the species, except when the inhabitant itself is present, or when any other grounds of ambiguity arise, we must reject, or lay small stress upon, the evidence, lest we vitiate our general results by false identifications and analogies. We cannot do better than consider the steps by which the science of botanical geography has reached its present stage of advancement, and endeavour to introduce the same severe comparison of the specific characters, in drawing all our geological inferences.

Tables of shells by M. Deshayes.—In the Appendix the reader will find a tabular view of the results obtained by the comparison of more than three thousand tertiary shells, with nearly five thousand living species, all of which, with few exceptions, are contained in the rich collection of M. Deshayes. Having enjoyed an opportunity of examining, again and again, the specimens on which this eminent conchologist has founded his identifica-

* See vol. i. chap. vi.

tions, and having been witness to the great time and labour devoted by him to this arduous work, I feel confidence in the results, so far as the data given in his list will carry us. It was necessary to compare nearly forty thousand specimens, in order to construct these tables, since not only the varieties of every species required examination, but the different individuals, also, belonging to each which had been found fossil in various localities. The correctness of the localities themselves was ascertained with scrupulous exactness, together with the relative position of the strata; and if any doubts existed on these questions, the specimens were discarded as of no geological value. A large proportion of the shells were procured, by M. Deshayes himself, from the Paris basin, many were contributed by different French geologists, and some were collected by myself from different parts of Europe.

It would have been impossible to give lists of more than three thousand fossil shells in a work not devoted exclusively to conchology; but we were desirous of presenting the reader with a catalogue of those fossils which M. Deshayes has been able to identify with living species, as also of those which are common to two distinct tertiary eras. By this means a comparison may be made of the testacea of each geological epoch, with the actual state of the organic creation, and, at the same time, the relations of different tertiary deposits to each other exhibited. The number of shells mentioned by name in the tables, in order to convey this information, is seven hundred and eighty-two, of which four hundred and twenty-six have been found both living and fossil, and three hundred and fifty-six fossil only, but in the deposits of more than one era. An exception, however, to the strictness of this rule, has been made in regard to the fossil shells common to the London and Paris basins, fifty-one of which have been enumerated by name, though these formations do not belong to different eras.

It has been more usual for geologists to give tables of characteristic shells; that is to say, of those found in the strata of one period and not common to any other. These typical species are certainly of the first importance, and some of them

will be seen figured in the plates, illustrative of the different tertiary eras; but we were more anxious, in this work, to place in a clear light, a point of the greatest theoretical interest, which has been often overlooked or controverted, viz., the identity of many living and fossil species, as also the connexion of the zoological remains of deposits formed at successive periods.

The value of such extensive comparisons, as those of which the annexed tables of M. Deshayes give the results, depends greatly on the circumstance, that all the identifications have been made by the same naturalist. The amount of variation which ought to determine a species is, in cases where they approach near to each other, a question of the nicest discrimination, and requires a degree of judgment and tact that can hardly be possessed by different zoologists in exactly the same degree. The standard, therefore, by which differences are to be measured, can scarcely ever be perfectly invariable, and one great object to be sought for is, that, at least, it should be uniform. If the distinctions are all made by the same naturalist, and his knowledge and skill be considerable, the results may be relied on with sufficient confidence, as far as regards our geological conclusions.

If one conchologist should inform us that out of 1122 species of fossil testacea, discovered in the Paris basin, he has only been enabled to identify thirty-eight with recent species, while another should declare, that out of two hundred and twenty-six Sicilian fossil shells, no less than two hundred and sixteen belonged to living species, we might suspect that one of these observers allowed a greater degree of latitude to the variability of the specific character than the other; but when, in both instances, the conclusions are drawn by the same eminent conchologist, we are immediately satisfied that the relations of these two groups, to the existing state of the animate creation, are as distinct as are indicated by the numerical results.

It is not pretended that the tables, to which we refer, comprise all the known tertiary shells. In the museums of Italy there are magnificent collections, to which M. Deshayes had no

access, and the additions to the recent species in the cabinets of conchologists in London, have been so great of late years, that in many extensive genera the number of species has been more than doubled. But as the greater part of these newly-discovered shells have been brought from the Pacific and other distant seas, it is probable that these accessions would not materially alter the results given in the tables, and it must, at all events, be remembered, that the only effect of such additional information would be, to increase the number of identifications of recent with fossil species, while the proportional number of analogues in the different periods might probably remain nearly the same.

SUBDIVISIONS OF THE TERTIARY EPOCH.

Recent formations.—We shall now proceed to consider the subdivisions of tertiary strata which may be founded on the results of a comparison of their respective fossils, and to give names to the periods to which they each belong. The tertiary epoch has been divided into three periods in the tables; we shall, however, endeavour to establish *four*, all distinct from the actual period, or that which has elapsed since the earth has been tenanted by man. To the events of this latter era, which we shall term the *recent*, we have exclusively confined ourselves in the two preceding volumes. All sedimentary deposits, all volcanic rocks, in a word, every geological monument, whether belonging to the animate or inanimate world, which appertains to this epoch, may be termed *recent*. Some *recent* species, therefore, are found *fossil* in various tertiary periods, and, on the other hand, others, like the Dodo, may be *extinct*, for it is sufficient that they should once have coexisted with man, to make them referrible to this era.

Some authors apply the term *contemporaneous* to all the formations which have originated during the human epoch; but as the word is so frequently in use to express the synchronous origin of distinct formations, it would be a source of great inconvenience and ambiguity, if we were to attach to it a technical sense.

We may sometimes prove, that certain strata belong to the recent period by aid of historical evidence, as parts of the delta of the Po, Rhone, and Nile, for example; at other times, by discovering imbedded remains of man or his works; but when we have no evidence of this kind, and we hesitate whether to ascribe a particular deposit to the recent era, or that immediately preceding, we must generally incline to refer it to the latter, for it will appear in the sequel, that the changes of the historical era are quite insignificant when contrasted with those even of the newest tertiary period.

Newer Pliocene period.—This most modern of the four subdivisions of the whole tertiary epoch, we propose to call the *Newer Pliocene*, which, together with the *Older* Pliocene, constitute one group in the annexed tables of M. Deshayes.

We derive the term Pliocene from πλειων, major, and καινος, recens, as the major part of the fossil testacea of this epoch are referrible to recent species*. Whether in all cases there may hereafter prove to be an absolute preponderance of recent species, in every group of strata assigned to this period in the tables, is very doubtful; but the proportion of living species, where least considerable, usually approaches to one-half of the total number, and appears always to exceed a third; and as our acquaintance with the testacea of the Mediterranean, and some other seas, increases, it is probable that a greater proportion will be identified.

* In the terms Pliocene, Miocene, and Eocene, the Greek diphthongs *ei* and *ai* are changed into the vowels *i* and *e*, in conformity with the idiom of our language. Thus we have Encenia, an inaugural ceremony, derived from εν and καινος, recens; and as examples of the conversion of *ei* into *i*, we have icosahedron.

I have been much indebted to my friend, the Rev. W. Whewell, for assisting me in inventing and anglicizing these terms, and I sincerely wish that the numerous foreign diphthongs, barbarous terminations, and Latin plurals, which have been so plentifully introduced of late years into our scientific language, had been avoided as successfully as they are by French Naturalists, and as they were by the earlier English writers, when our language was more flexible than it is now. But while I commend the French for accommodating foreign terms to the structure of their own language, I must confess that no naturalists have been more unscholarlike in their mode of fabricating Greek derivatives and compounds, many of the latter being a bastard offspring of Greek and Latin.

The newer Pliocene formations, before alluded to, pass insensibly into those of the *Recent* epoch, and contain an immense preponderance of recent species. It will be seen that of two hundred and twenty-six species, found in the Sicilian beds, only ten are of extinct or unknown species, although the antiquity of these tertiary deposits, as contrasted with our most remote historical eras, is immensely great. In the volcanic and sedimentary strata of the district round Naples, the proportion appears to be even still smaller.

Older Pliocene period.—These formations, therefore, and others wherein the plurality of living species is so very decided, we shall term the *Newer* Pliocene, while those of the tertiary period immediately preceding may be called the *Older* Pliocene. To the latter belong the formations of Tuscany, and of the Subapennine hills in the north of Italy, as also the English Crag.

It appears that in the period last mentioned, the proportion of recent species varies from upwards of a third to somewhat more than half of the entire number; but it must be recollected, that this relation to the recent epoch is only *one* of its zoological characters, and that certain *peculiar species* of testacea also distinguish its deposits from all other strata. The relative position of the beds referrible to this era has been explained in diagrams Nos. 3 and 4, letter *f*, chapter II.

Miocene period.—The next antecedent tertiary epoch we shall name Miocene, from μειων, minor, and καινος, recens, a minority only of fossil shells imbedded in the formations of this period, being of recent species. The total number of Miocene shells, referred to in the annexed tables, amounts to 1021, of which one hundred and seventy-six only are recent, being in the proportion of rather less than eighteen in one hundred. Of species common to this period, and to the two divisions of the Pliocene epoch before alluded to, there are one hundred and ninety-six, whereof one hundred and fourteen are living, and the remaining eighty-two extinct, or only known as fossil.

As there are a certain number of fossil species which are characteristic of the Pliocene strata before described, so also

there are many shells exclusively confined to the Miocene period. We have already stated, that in Touraine and in the South of France near Bordeaux, in Piedmont, in the basin of Vienna, and other localities, these Miocene formations are largely developed, and their relative position has been shown in diagrams Nos. 3 and 4, letter *e*, chapter II.

Eocene period.—The period next antecedent we shall call Eocene, from ἠως, aurora, and καινος, recens, because the extremely small proportion of living species contained in these strata, indicates what may be considered the first commencement, or *dawn,* of the existing state of the animate creation. To this era the formations first called tertiary, of the Paris and London basins, are referrible. Their position is shown in the diagrams Nos. 3 and 4, letter *d*, in the second chapter.

The total number of fossil shells of this period already known, is one thousand two hundred and thirty-eight, of which number forty-two only are living species, being nearly in the proportion of three and a half in one hundred. Of fossil species, not known as recent, forty-two are common to the Eocene and Miocene epochs. In the Paris basin alone, 1122 species have been found fossil, of which thirty-eight only are still living.

The geographical distribution of those recent species which are found fossil in formations of such high antiquity as those of the Paris and London basins, is a subject of the highest interest.

It will be seen by reference to the tables, that in the more modern formations, where so large a proportion of the fossil shells belong to species still living, they also belong, for the most part, to species now inhabiting the seas immediately adjoining the countries where they occur fossil; whereas the recent species, found in the older tertiary strata, are frequently inhabitants of distant latitudes, and usually of warmer climates. Of the forty-two Eocene species, which occur fossil in England, France, and Belgium, and which are still living, about half now inhabit within, or near the tropics, and almost all the rest are denizens of the more southern parts of Europe. If some

Eocene species still flourish in the same latitudes where they are found fossil, they are species which, like *Lucina divaricata,* are now found in many seas, even those of different quarters of the globe, and this wide geographical range indicates a capacity of enduring a variety of external circumstances, which may enable a species to survive considerable changes of climate and other revolutions of the earth's surface. One fluviatile species (*Melania inquinata*), fossil in the Paris basin, is now only known in the Philippine islands, and during the lowering of the temperature of the earth's surface, may perhaps have escaped destruction by transportation to the south. We have pointed out in the second volume (chap. vii.), how rapidly the eggs of freshwater species might, by the instrumentality of water-fowl, be transported from one region to another. Other Eocene species, which still survive and range from the temperate zone to the equator, may formerly have extended from the pole to the temperate zone, and what was once the southern limit of their range may now be the most northern.

Even if we had not established several remarkable facts in attestation of the longevity of certain tertiary species, we might still have anticipated that the duration of the living species of aquatic and terrestrial testacea would be very unequal. For it is clear that those which now inhabit many different regions and climates, may survive the influence of destroying causes, which might extirpate the greater part of the species now living. We might expect, therefore, some species to survive several successive states of the organic world, just as Nestor was said to have outlived three generations of men.

The distinctness of periods may indicate our imperfect information.—In regard to distinct zoological periods, the reader will understand, from our observations in the third chapter, that we consider the wide lines of demarcation that sometimes separate different tertiary epochs, as quite unconnected with extraordinary revolutions of the surface of the globe, and as arising, partly, like chasms in the history of nations, out of the present imperfect state of our information, and partly from

the irregular manner in which geological memorials are preserved, as already explained. We have little doubt that it will be necessary hereafter to intercalate other periods, and that many of the deposits, now referred to a single era, will be found to have been formed at very distinct periods of time, so that, notwithstanding our separation of tertiary strata into four groups, we shall continue to use the term *contemporaneous* with a great deal of latitude.

We throw out these hints, because we are apprehensive lest zoological periods in Geology, like artificial divisions in other branches of Natural History, should acquire too much importance, from being supposed to be founded on some great interruptions in the regular series of events in the organic world, whereas, like the genera and orders in zoology and botany, we ought to regard them as invented for the convenience of systematic arrangement, always expecting to discover intermediate gradations between the boundary lines that we have first drawn.

In Natural History we select a certain species as a generic type, and then arrange all its congeners in a series, according to the degrees of their deviation from that type, or according as they approach to the characters of the genus which precedes or follows. In like manner, we may select certain Geological formations as typical of particular epochs; and having accomplished this step, we may then arrange the groups referred to the same period in chronological order, according as they deviate in their organic contents from the *normal* groups, or according as they approximate to the type of an antecedent or subsequent epoch.

If intermediate formations shall hereafter be found between the Eocene and Miocene, and between those of the last period and the Pliocene, we may still find an appropriate place for all, by forming subdivisions on the same principle as that which has determined us to separate the lower from the upper Pliocene groups. Thus, for example, we might have three divisions of the Eocene epoch,—the older, middle, and newer; and

three similar subdivisions, both of the Miocene and Pliocene epochs. In that case, the formations of the middle period must be considered as the types from which the assemblage of organic remains in the groups immediately antecedent or subsequent will diverge.

The Recent strata form a common point of departure in all countries.—We derive one great advantage from beginning our classification of formations by a comparison of the fossils of the more recent strata with the species now living, namely, the acquisition of a common point of departure in every region of the globe. Thus, for example, if strata should be discovered in India or South America, containing the same small proportion of recent shells as are found in the Paris basin, *they* also might be termed Eocene, and, on analogous data, an approximation might be made to the relative dates of strata placed in the arctic and tropical regions, or the comparative age ascertained of European deposits, and those which are trodden by our antipodes.

There might be no species common to the two groups; yet we might infer their synchronous origin from the common relation which they bear to the existing state of the animate creation. We may afterwards avail ourselves of the dates thus established, as eras to which the monuments of preceding periods may be referred.

Numerical proportion of recent shells in the different Tertiary periods.—There are seventeen species of shells discovered, which are common to all the tertiary periods, thirteen of which are still living, while four are extinct, or only known as fossil*. These seventeen species show a connexion between all these geological epochs, whilst we have seen that a much greater number are common to the Eocene and Miocene periods, and a still greater to the Miocene and Pliocene.

We have already stated, that in the older tertiary formations, we find a very small proportion of fossil species identical with

* See the Tables of M. Deshayes in Appendix I.

those now living, and that, as we approach the superior and newer sets of strata, we find the remains of existing animals and plants in greater abundance. It is almost as difficult to find an unknown species in some of the newer Pliocene deposits, although very ancient and elevated at great heights above the level of the sea, as to meet with recent species in the Eocene strata.

This increase of existing species, and gradual disappearance of the extinct, as we trace the series of formations from the older to the newer, is strictly analogous, as we before observed, to the fluctuations of a population such as might be recorded at successive periods, from the time when the oldest of the individuals now living was born to the present moment. The disappearance of persons who never were contemporaries of the greater part of the present generation, would be seen to have kept pace with the birth of those who now rank amongst the oldest men living, just as the Eocene and Miocene species are observed to have given place to those Pliocene testacea which are now contemporary with man.

In reference to the organic remains of the different groups which we have named, we may say that about a thirtieth part of the Eocene shells are of recent species, about one-fifth of the Miocene, more than a third, and often more than half, of the older Pliocene, and nine-tenths of the newer Pliocene.

Mammiferous remains of the successive tertiary eras.—But although a thirtieth part of the Eocene testacea have been identified with species now living, none of the associated mammiferous remains belong to species which now exist, either in Europe or elsewhere. Some of these equalled the horse, and others the rhinoceros, in size, and they could not possibly have escaped observation, had they survived down to our time. More than forty of these Eocene mammifers are referrible to a division of the order Pachydermata, which has now only four living representatives on the globe. Of these, not only the species but the genera are distinct from any of those which have been established for the classification of living animals.

In the Miocene mammalia we find a few of the generic forms most frequent in the Eocene strata associated with some of those now existing, and in the Pliocene we find an intermixture of extinct and recent species of quadrupeds. There is, therefore, a considerable degree of accordance between the results deducible from an examination of the fossil testacea, and those derived from the mammiferous fossils. But although the latter are more important in respect to the unequivocal evidence afforded by them of the extinction of species, yet, for reasons before explained, they are of comparatively small value in the general classification of strata in Geology.

It will appear evident, from what we have said in the last volume respecting the fossilization of terrestrial species, that the imbedding of their remains depends on rare casualties, and that they are, for the most part, preserved in detached alluvions covering the emerged land, or in osseous breccias and stalagmites formed in caverns and fissures, or in isolated lacustrine formations. These fissures and caves may sometimes remain open during successive geological periods, and the alluvions, spread over the surface, may be disturbed, again and again, until the mammalia of successive epochs are mingled and confounded together. Hence we must be careful, when we endeavour to refer the remains of mammalia to certain tertiary periods, that we ascertain, not only their association with testacea of which the date is known, but, also, that the remains were intermixed in such a manner as to leave no doubt of the former coexistence of the species.

In the next page will be found a Synoptical Table of the Recent and Tertiary formations alluded to in this chapter.

N.B. By aid of this table, the reader will be able to refer almost all the localities of the Pliocene formations enumerated in the Tables of M. Deshayes (Appendix I.) to the newer or older division of the Pliocene period established in the foregoing chapter.

Synoptical Table of Recent and Tertiary Formations.

PERIODS.		Character of Formations.	Localities of the different Formations.
I. RECENT.	. . . .	Marine.	Coral formations of Pacific. Delta of Po, Ganges, &c.
		Freshwater.	Modern deposits in Lake Superior—Lake of Geneva—Marl lakes of Scotland—Italian travertin, &c.
		Volcanic.	Jorullo — Monte Nuovo — Modern lavas of Iceland, Etna, Vesuvius, &c.
II. TERTIARY.	1. Newer Pliocene.	Marine.	Strata of the Val di Noto in Sicily. Ischia, Morea? Uddevalla.
		Freshwater.	Valley of the Elsa around Colle in Tuscany.
		Volcanic.	Older parts of Vesuvius, Etna, and Ischia—Volcanic rocks of the Val di Noto in Sicily.
	2. Older Pliocene.	Marine.	Northern Subapennine formations, as at Parma, Asti, Sienna, Perpignan, Nice—English Crag.
		Freshwater.	Alternating with marine beds near the town of Sienna.
		Volcanic.	Volcanos of Tuscany and Campagna di Roma.
	3. Miocene.	Marine.	Strata of Touraine, Bordeaux, Valley of the Bormida, and the Superga near Turin—Basin of Vienna.
		Freshwater.	Alternating with marine at Saucats, twelve miles south of Bordeaux.
		Volcanic.	Hungarian and Transylvanian volcanic rocks. Part of the volcanos of Auvergne, Cantal, and Velay?
	4. Eocene.	Marine.	Paris and London Basins.
		Freshwater.	Alternating with marine in Paris basin—Isle of Wight—purely lacustrine in Auvergne, Cantal, and Velay.
		Volcanic.	Oldest part of volcanic rocks of Auvergne.

CHAPTER VI.

Newer Pliocene formations—Reasons for considering in the first place the more modern periods—Geological structure of Sicily—Formations of the Val di Noto of newer Pliocene period—Divisible into three groups—Great limestone—Schistose and arenaceous limestone—Blue marl with shells—Strata subjacent to the above—Volcanic rocks of the Val di Noto—Dikes—Tuffs and Peperinos—Volcanic conglomerates—Proofs of long intervals between volcanic eruptions—Dip and direction of newer Pliocene strata of Sicily.

NEWER PLIOCENE FORMATIONS.

HAVING endeavoured, in the last chapter, to explain the principles on which the different tertiary formations may be arranged in chronological order, we shall now proceed to consider the newest division of formations, or that which we have named the newer Pliocene.

It may appear to some of our readers, that we reverse the natural order of historical research by thus describing, in the first place, the monuments of a period which immediately preceded our own era, and passing afterwards to the events of antecedent ages. But, in the present state of our science, this retrospective order of inquiry is the only one which can conduct us gradually from the known to the unknown, from the simple to the more complex phenomena. We have already explained our reasons for beginning this work with an examination, in the first two volumes, of the events of the *recent* epoch, from which the greater number of rules of interpretation in geology may be derived. The formations of the newer Pliocene period will be considered next in order, because these have undergone the least degree of alteration, both in position and internal structure, subsequently to their origin. They are monuments of which the characters are more easily deciphered than those belonging to more remote periods, for they have been less mutilated by the hand of time. The organic remains, more

especially of this era, are most important, not only as being in a more perfect state of preservation, but also as being chiefly referrible to species now living; so that their habits are known to us by direct comparison, and not merely by inference from analogy, as in the case of extinct species.

Geological structure of Sicily.—We shall first describe an extensive district in Sicily, where the newer Pliocene strata are largely developed, and where they are raised to considerable heights above the level of the sea. After presenting the reader with a view of these formations, we shall endeavour to explain the manner in which they originated, and speculate on the subterranean changes of which their present position affords evidence.

The island of Sicily consists partly of primary and secondary rocks, which occupy, perhaps, about two-thirds of its superficial area*, and the remaining part is covered by tertiary formations, which are of great extent in the southern and central parts of the island, while portions are found bordering nearly the whole of the coasts.

Formations of the Val di Noto.—If we first turn our attention to the Val di Noto, a district which intervenes between Etna and the southern promontory of Sicily, we find a considerable tract, containing within it hills which are from one to two thousand feet in height, entirely composed of limestone, marl, sandstone, and associated volcanic rocks, which belong to the newer Pliocene era. The recent shells of the Mediterranean abound throughout the sedimentary strata, and there are abundant proofs that the igneous rocks were the produce of successive submarine eruptions, repeated at intervals during the time when the subaqueous formations were in progress.

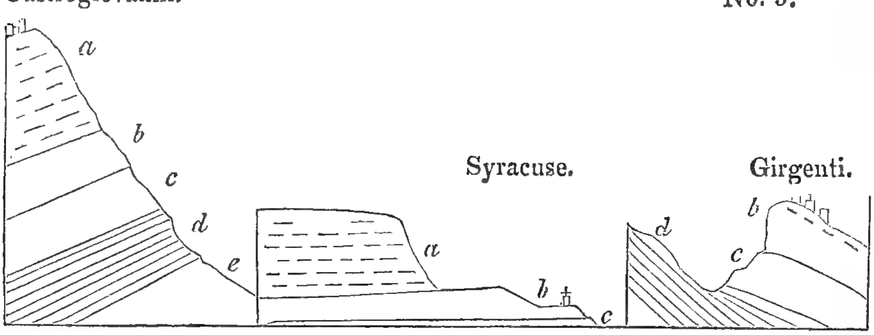
These rising grounds of the Val di Noto are separated from the cone of Etna, and the marine strata whereon it rests, by the low level plain of Catania, just elevated above the level of the sea, and watered by the Simeto. The traveller who passes

* We may shortly expect a full account of the Geology of this island from Professor Hoffmann, who has devoted more than a year to its examination.

from Catania to Syracuse, has an opportunity of observing, on the sides of the valley, many deep sections of the modern formations above described, especially if he makes a slight detour by Sortino and the Valley of Pentalica.

The whole series of strata, in the Val di Noto, is divisible into three principal groups, exclusive of the associated volcanic rocks. The uppermost mass consists of limestone, which sometimes acquires the enormous thickness of seven or eight hundred feet, below which is a series much inferior in thickness, consisting of a calcareous sandstone, conglomerate and schistose limestone, and beneath this again, blue marl. The whole of the above groups contain shells and zoophytes, nearly all of which are referrible to species now inhabiting the contiguous sea.

No. 5.



a, Great limestone of Val di Noto.
b, Schistose and arenaceous limestone of Floridia, &c.
c, Blue marl with shells.
d, White laminated marl.
e, Blue clay and gypsum, &c. without shells.

Great limestone formation (*a*, diagram No. 5).—In mineral character this rock often corresponds to the yellowish white building-stone of Paris, well known by the name of *Calcaire grossier*, but it often passes into a much more compact stone. In the deep ravine-like valleys of Sortino and Pentalica, it is seen in nearly horizontal strata, as solid and as regularly bedded as the greater part of our ancient secondary formations. It abounds in natural caverns, which, in many places, as in the valley of Pentalica, have been enlarged and multiplied by artificial excavations.

The shells in the limestone are often very indistinct, sometimes nothing but casts remaining, but in many localities, especially where there is a slight intermixture of volcanic sand, they are more entire, and, as we have already stated, can almost all be identified with recent Mediterranean testacea. Several species of the genus Pecten, are exceedingly numerous, particularly the large scallop (*P. Jacobæus*), now so common on the coasts of Sicily. The shells which I collected from this limestone at Syracuse, Villasmonde, Militello (V. di Noto), and Girgenti, have been examined by M. Deshayes, and found to be all referrible to species now living, with three or four exceptions*.

The mineral characters of this great calcareous formation vary considerably in different parts of the island. In the south, near the town of Noto, the rock puts on the compactness, together with the spheroidal concretionary structure of some of the Italian travertins. At the same place, also, it contains the leaves of plants and reeds, as if a stream of freshwater, charged with carbonate of lime and terrestrial vegetable remains, had entered the sea in the neighbourhood. At Spaccaforno, and other places in the south of Sicily, a similar compact variety of the limestone occurs, where it is for the most part pure white, often very thick bedded, and occasionally without any lines of stratification. This hard white rock is often four or five hundred feet in thickness, and appears to contain no fossil shells. It has much the appearance of having been precipitated from the waters of mineral springs, such as frequently rise up at the bottom of the sea in the volcanic regions of the Mediterranean. As these springs give out an equal quantity of mineral matter at all seasons, they are much more likely to give rise to unstratified masses, than a river which is swoln and charged with

* For lists of these see Appendix II. I procured at Villasmonde, seven species; at Militello, ten; in the limestone of Girgenti, of which the ancient temples are built, ten species; from the limestone and subjacent clay at Syracuse, twenty-six species; in the limestone and clay near Palermo, also belonging to the newer Pliocene formation, one hundred shells.

sedimentary matter of different kinds, and in unequal quantities, at particular seasons of the year.

The great limestone, above mentioned, prevails not only in the Val di Noto, but reappears in the centre of the island, capping the hill of Castrogiovanni, at the height of three thousand feet above the level of the sea. It is cavernous there, as at Sortino and Syracuse, and contains fossil shells and casts of shells of the same species*.

Schistose and arenaceous limestone, &c. (*b*, diagram No. 5).—The limestone above-mentioned passes downwards into a white calcareous sand, which has sometimes a tendency to an oolitic and pisolitic structure, analogous to that which we have described when speaking of the travertin of Tivoli†. At Floridia, near Syracuse, it contains a sufficient number of small calcareous pebbles to constitute a conglomerate, where also beds of sandy limestone are associated, replete with numerous fragments of shells, and much resembling, in structure, the English cornbrash. A diagonal lamination is often observable in the calcareous sandy beds analogous to that represented in the first volume (chap. xiv. diagram No. 6), and to that exhibited in many sections of the English crag, to which we shall afterwards allude.

In some parts of the island this sandy calcareous division, *b*, seems to be represented by yellow sand, exactly resembling that so frequently superimposed on the blue shelly marl of the Subapennines in the Italian peninsula. Thus, near Grammichele, on the road to Caltagirone, beds of incoherent yellow sand, several hundred feet in thickness, with occasional layers of shells, repose upon the blue shelly marl of Caltagirone.

When we consider the arenaceous character of this formation, the disposition of the laminæ, and the broken shells sometimes imbedded in it, it is difficult not to suspect that it was

* Dr. Daubeny correctly identified the Val di Noto limestone of Syracuse with that of the summit of Castrogiovanni.—Jameson, Ed. Phil. Journ., No. xxv. p. 107, July, 1825.

† Vol. i. chap. xii.

formed in shallower water, and nearer the action of superficial currents, than the superincumbent limestone, which was evidently accumulated in a sea of considerable depth. If we adopt this view, we must suppose a considerable subsidence of the bed of the sea, subsequent to the deposition of the arenaceous beds in the Val di Noto.

Blue marl with shells (*c*, diagram No. 5).—Under the sandy beds, last mentioned, is found an argillaceous deposit of variable thickness, called *Creta* in Sicily. It resembles the blue marl of the Subapennine hills, and, like it, encloses fossil shells and corals in a beautiful state of preservation. Of these I collected a great abundance from the clay, on the south side of the harbour of Syracuse, and twenty species in the environs of Caltanisetta, all of which, with three exceptions, M. Deshayes was able to identify with recent species *. From similar blue marl, alternating with yellow sand, at Caltagirone, at an elevation of about five hundred feet above the level of the sea, I obtained forty species of shells, of which all but six were recognized as identical with recent species †. The position of this argillaceous formation is well seen at Castrogiovanni and Girgenti, as represented in the sections, diagram No. 5. In both of these localities, the limestone of the Val di Noto re-appears, passing downwards into a calcareous sandstone, below which is a shelly blue clay.

Strata beneath the blue marl.—The clay rests, in both localities, on an older series of white and blue marls, probably belonging to the tertiary period, but of which I was unable to determine the age, having procured from it no organic remains save the skeletons of fish which I found in the white thinly-laminated marls ‡.

* See list of these shells, Appendix II.

† See Appendix II.

‡ I found these fossil fish in great abundance on the road, half a mile north-west of Radusa, on the road to Castrogiovanni, where the marls are fetid, and near Castrogiovanni in gypseous marls, at the mile-stone No. 88, and between that and No. 89. Lord Northampton has since presented to the Geological Society

These marls are sometimes gypseous, and belong to a great argillaceous formation which stretches over a considerable part of Sicily, and contains sulphur and salt in great abundance. The strata of this group have been in some places contorted in the most extraordinary manner, their convolutions often resembling those seen in the most disturbed districts of primary clay slate.

But we wish, at present, to direct the reader's exclusive attention to strata decidedly referrible to the newer Pliocene era, and we have yet to mention the igneous rocks associated with the sedimentary formations already alluded to.

Volcanic Rocks of the Val di Noto.—The volcanic rocks occasionally associated with the limestones, sands, and marls already described, constitute a very prominent feature throughout the Val di Noto. Great confusion might have been expected to prevail, where lava and ejected sand and scoriæ are intermixed with the marine strata, and, accordingly, we find it often impossible to recognize the exact part of the series to which the beds thus interfered with belong.

Sometimes there are proofs of the posterior origin of the lava, and sometimes of the newer date of the stratified rock, for we find dikes of lava intersecting both the marl and limestone, while, in other places, calcareous beds repose upon lava, and are unaltered at the point of contact. Thus the shelly limestone of Capo Santa Croce rests in horizontal strata upon a mass of lava, which had evidently been long exposed to the action of the waves, so that the surface has been worn perfectly smooth. The limestone is unchanged at its junction with the igneous rock, and incloses within it pebbles of the lava*.

The volcanic formations of the Val di Noto usually consist of the most ordinary variety of basalt with or without olivine. The rock is sometimes compact, often very vesicular. The

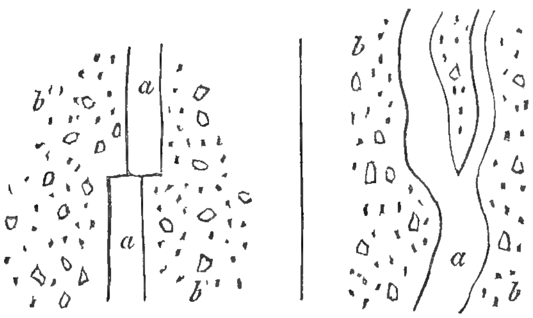
some which he obtained from the same localities, but I have met with no zoologists who could name the species.

* This locality is described by Professor Hoffmann, Archiv für Mineralogie, &c. Berlin, 1831.

vesicles are occasionally empty, both in dikes and currents, and are in some localities filled with calcareous spar, arragonite, and zeolites. The structure is, in some places, spheroidal, in others, though rarely, columnar. I found dikes of amygdaloid, wacke, and prismatic basalt, intersecting the limestone at the bottom of the hollow, called Gozzo degli Martiri, below Melilli.

Dikes.—Dikes of vesicular and amygdaloidal lava are also seen traversing peperino, west of Palagonia, near a mill by the road side.

No. 6. No. 7.



Horizontal section of Dikes near Palagonia.

a, Lava.
b, Peperino, consisting of volcanic sand, mixed with fragments of lava and of limestone.

In this case we may suppose the peperino to have resulted from showers of volcanic sand and scoriæ, together with fragments of limestone thrown out by a submarine explosion, similar to that which lately gave rise to the volcanic island off Sciacca. When the mass was, to a certain degree, consolidated, it may have been rent open, so that the lava ascended through fissures, the walls of which were perfectly even and parallel. After the melted matter that filled the rent had cooled down, it must have been fractured and shifted horizontally by a lateral movement.

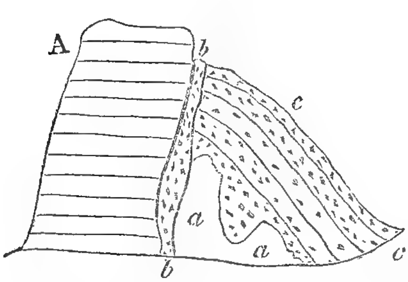
In the second figure, No. 7, the lava has more the appearance of a vein which forced its way through the peperino, availing itself, perhaps, of a slight passage opened by rents caused by earthquakes. Some of the pores of the lava, in these dikes, are empty, while others are filled with carbonate of lime.

The annexed diagrams (Nos. 6 and 7) represent a ground plan of the rocks as they are exposed to view on a horizontal surface. We think it highly probable that similar appearances would be seen, if we could examine the floor of the sea in that part of the Mediterranean where the waves have recently washed away the new volcanic island, for when a superincumbent mass of ejected fragments has been removed by denudation, we may expect to see sections of dikes traversing tuff, or, in other words, sections of the channels of communication by which the subterranean lavas reached the surface.

On the summit of the limestone platform of the Val di Noto, I more than once saw analogous dikes, not only of lava but of volcanic tuff, rising vertically through the horizontal strata, and having no connexion with any igneous masses now apparent on the surface. In regard to the *dikes of tuff or peperino*, we may suppose them to have been open fissures at the bottom of the sea, into which volcanic sand and scoriæ were drifted by a current.

Tuffs and Peperinos.—In the hill of Novera, between Vizzini and Militelli, a mass of limestone, horizontally stratified, comes in contact with inclined strata of tuff (see diagram No. 8),

No. 8.



A, Limestone.
aa, Calcareous breccia with fragments of lava.
b, Black tuff.
c, Tuff.

while a mixed calcareous and volcanic breccia, *a a*, supports the inclined layers of tuff, *c*. The vertical fissure, *b b*, is filled with volcanic sand of a different colour. An inspection of this section will convince the reader that the limestone must have been greatly dislocated during the time that the submarine eruptions were taking place.

At the town of Vizzini, a dike of lava intersects the argillaceous strata, and converts them into siliceous schist, which has

been contorted and shivered into an immense number of fragments.

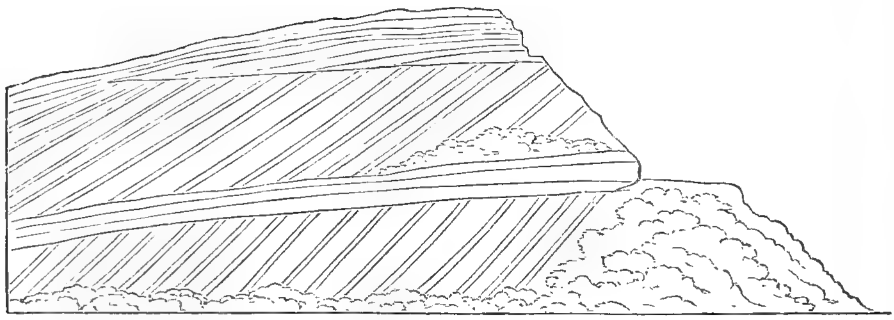
We have stated that the beds of limestone, clay, and sand, in the Val di Noto, are often partially intermixed with volcanic ejections, such as may have been showered down into the sea during eruptions, or may have been swept by rivers from the land. When the volcanic matter predominates, these compound rocks constitute the peperinos of the Italian mineralogists, some of which are highly calcareous, full of shells, and extremely hard, being capable of a high polish like marble. In some parts of the Val di Noto they are variously mottled with spots of red and yellow, and contain small angular fragments, similar to the lapilli thrown from volcanos.

It is recorded that, during the late eruption off the southern coast of Sicily, opposite Sciacca, the sea was in a state of violent ebullition, and filled, for several weeks continuously, with red or chocolate-coloured mud, consisting of finely-comminuted scoriæ. During this period, it is clear that the waves and currents that have since had power to sweep away the island, and disperse its materials far and wide over the bed of the sea, must with still greater ease have carried to vast distances the fine red mud, which was seen boiling up from the bottom, so that it may have entered largely into the composition of modern peperinos.

Professor Hoffmann relates that, during the eruption (June, 1831), the surface of the sea was strewed over, at the distance of thirty miles from the new volcano, with so dense a covering of scoriæ, that the fishermen were obliged to part it with their oars, in order to propel their boats through the water. It is, therefore, quite consistent with analogy, that we should find the ancient tuffs and peperinos so much more generally distributed than the submarine lavas.

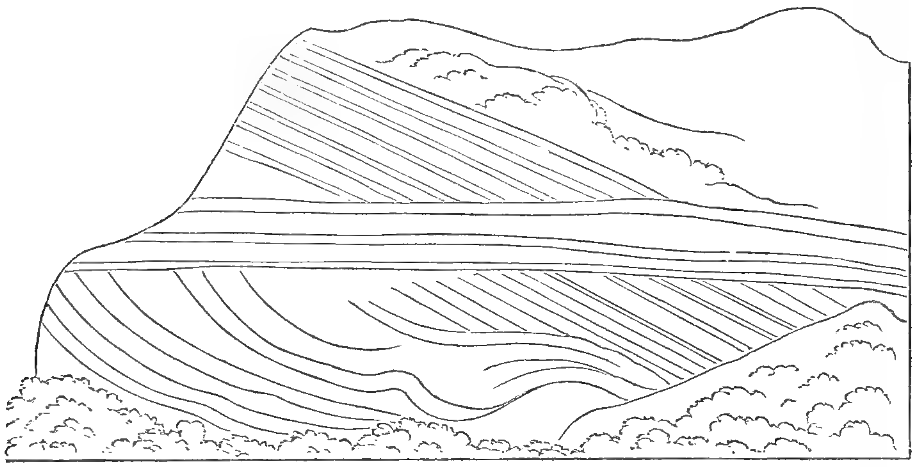
In the road which leads from Palagonia to Lago Naftia, and at the distance of about a mile and a half from the former place, there is a small pass where the hills, on both sides, consist of a calcareous grit, intermixed with some grains of volcanic sand.

No. 9.



Section of calcareous grit and peperino, east of Palagonia. South side of pass. Vertical height about thirty feet.

No. 10.



Section of the same beds on the north side of the pass.

The disposition of the strata, on both sides of the pass, is most singular, and remarkably well exposed, as the harder layers have resisted the weathering of the atmosphere and project in relief. The sections exhibited on both sides of the pass are nearly vertical, and do not exactly correspond, as will be seen in the annexed diagrams (Nos. 9 and 10). It is somewhat difficult to conceive in what manner this arrangement of the layers was occasioned, but we may, perhaps, suppose it to have arisen from the throwing down of calcareous sand and volcanic matter, upon steep slanting banks at the bottom of the sea, in which case they might have accumulated at various angles of between thirty and fifty degrees, as may be frequently seen in the sections of volcanic cones in Ischia and elsewhere. The denuding power of the waves may, then, have cut off the upper

portion of these banks, so that nearly horizontal layers may have been superimposed unconformably, after which another bank may have been formed in a similar manner to the first.

Volcanic conglomerates.—In the Val di Noto we sometimes meet with conglomerates entirely composed of volcanic pebbles. They usually occur in the neighbourhood of masses of lava, and may, perhaps, have been the shingle produced by the wasting cliffs of small islands in a volcanic archipelago. The formation of similar beds of volcanic pebbles may now be seen in progress on the beach north of Catania, where the waves are undermining one of the modern lavas of Etna; and the same may also be seen on the shores of Ischia.

Proofs of gradual accumulation.—In one part of the great limestone formation near Lentini, I found some imbedded volcanic pebbles, covered with full-grown serpulæ, supplying a beautiful proof of a considerable interval of time having elapsed between the rounding of these pebbles and their inclosure in a solid stratum. I also observed, not far from Vizzini, a very striking illustration of the length of the intervals which occasionally separated the flows of distinct lava-currents. A bed of oysters, perfectly identifiable with our common eatable species, no less than *twenty feet in thickness,* is there seen resting upon a current of basaltic lava; upon the oyster-bed again is superimposed a second mass of lava, together with tuff or peperino. Near Galieri, not far from the same locality, a horizontal bed, about a foot and a half in thickness, composed entirely of a common Mediterranean coral (*Caryophyllia cespitosa*, Lam.), is also seen in the midst of the same series of alternating igneous and aqueous formations. These corals stand erect as they grew, and after being traced for hundreds of yards, are again found at a corresponding height on the opposite side of the valley.

Dip and direction.—The disturbance which the newer Pliocene strata have undergone in Sicily, subsequent to their deposition, differs greatly in different places; in general, however, the beds are nearly horizontal, and are not often

highly inclined. The calcareous schists, on which part of the town of Lentini is built, are much fractured, and dip at an angle of twenty-five degrees to the north-west. In some of the valleys in the neighbourhood an anticlinal dip is seen, the beds on one side being inclined to the north-west, and on the other to the south-east.

Throughout a considerable part of Sicily which I examined, the dips of the tertiary strata were north-east and south-west; as, for example, in the district included between Terranuova, Girgenti, Caltanisetta, and Piazza, where there are several parallel lines, or ridges of elevation, which run north-west and south-east.

CHAPTER VII.

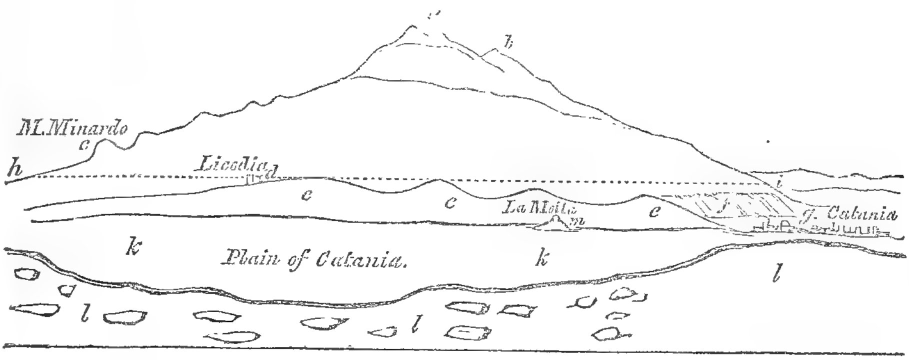
Marine and volcanic formations at the base of Etna—Their connexion with the strata of the Val di Noto—Bay of Trezza—Cyclopian isles—Fossil shells of recent species—Basalt and altered rocks in the Isle of Cyclops—Submarine lavas of the Bay of Trezza not currents from Etna—Internal structure of the cone of Etna—Val di Calanna—Val del Bove not an ancient crater—Its precipices intersected by countless dikes—Scenery of the Val del Bove—Form, composition, and origin of the dikes—Lavas and breccias intersected by them.

MARINE AND VOLCANIC FORMATIONS AT THE BASE OF ETNA.

The phenomena considered in the last chapter suggest many theoretical views of the highest interest in Geology; but before we enter upon these topics we are desirous of describing some formations in Valdemone, which are analogous to those of the Val di Noto, and to point out the relation of such rocks to the modern lavas of Etna.

If the traveller passes along the table-land, formed by the great limestone of the Val di Noto, until it terminates suddenly near Primosole, he there sees the plain of Catania at his feet,

No. 11.



View of Etna from the summit of the limestone platform of Primosole.

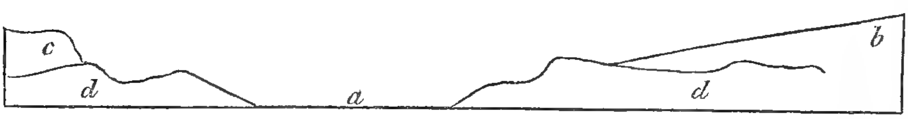
a, Highest cone. *b*, Montagnuola. *c*, Monte Minardo, with smaller lateral cones above. *d*, Town of Licodia dei Monaci. *e*, Marine formation called creta, argillaceous and sandy beds with a few shells, and associated volcanic rocks. *f*, Escarpment of stratified subaqueous volcanic tuff, &c., north-west of Catania. *g*, Town of Catania. *h*, *i*, Dotted line expressing the highest boundary along which the marine strata are occasionally seen. *k*, Plain of Catania. *l*, Limestone platform of Primosole of the newer Pliocene. *m*, La Motta di Catania.

and before him, to the north, the cone of Etna (see diagram No. 11). At the base of the cone he beholds a low line of hills *e*, *e* (No. 11), formed of clays and marls, associated with yellowish sand, similar to the formation provincially termed 'Creta,' in various parts of Sicily.

This marine formation, which is composed partly of volcanic and partly of sedimentary rocks, is seen to underlie the modern lavas of Etna. To what extent it forms the base of the mountain cannot be observed, for want of sections of the lower part of the cone, but the marine sub-Etnean beds are not observed to rise to a greater elevation than eight hundred, or, at the utmost, one thousand feet above the level of the sea. We should remind the reader, that the annexed drawing is not a section, but an outline view of Etna, as seen from Primosole, so that the proportional height of the volcanic cone, which is, in reality, ten times greater than that of the hills of 'Creta,' at its base, is not represented, the summit of the cone being ten or twelve miles more distant from the plain of Catania, than Licodia.

Connexion of the sub-Etnean strata with those of the Val di Noto.—These marine strata are found both on the southern and eastern foot of Etna, and it is impossible not to infer that they belong to the inferior argillaceous series of the Val di Noto, which they resemble both in mineral and organic characters. In one locality they appear on the opposite sides of the Valley of the Simeto, covered on the north by the lavas of Etna, and on the south by the Val di Noto limestone.

Val di Noto. No. 12. Etna.



Section from释Paternò by Lago di Naftia to Palagonia.

a, Plain of the Simeto. *b*, Base of the cone of Etna, composed of modern lavas. *c*, Limestone of the Val di Noto. *d*, Clay, sand, and associated submarine volcanic rocks.

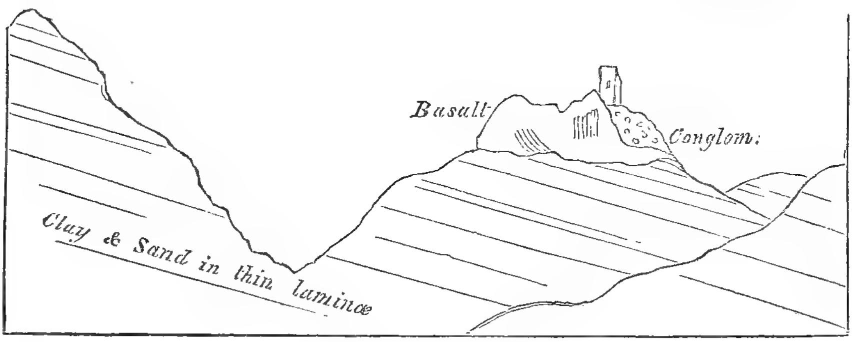
If in the country adjacent to the Lago di Naftia, through

which the annexed section is drawn, and in several other districts where the 'creta' prevails, together with associated submarine lavas, and where there is no limestone capping, a volcano should now burst forth, and give rise to a great cone, the position of such a cone would exactly correspond to that of the modern Etna, with relation to the rocks on which it rests.

Southern base of Etna.—The marine strata of clay and sand already alluded to, alternate in thin layers at the southern base of Etna, sometimes attaining a thickness of three hundred feet, or more, without any intermixture of volcanic matter. Crystals of selenite are dispersed through the clay, accompanied by a few shells, almost entirely of recent Mediterranean species. This formation of blue marl and yellow sand greatly resembles in character that of the Italian Subapennine beds, and, like them, often presents a surface denuded of vegetation, in consequence of the action of the rains on soft incoherent materials.

In travelling by Paternò, Misterbianco, and La Motta, we pass through deep narrow valleys excavated through these beds, which are sometimes capped, as at La Motta, by columnar basalt, accompanied by strata of tuff and volcanic conglomerate. (Diagram No. 13.)

No. 13.



La Motta near Catania.

The latter rock is composed of rolled masses of basalt, which may either have originated when first the lava was produced in a volcanic archipelago, or subsequently when the whole country was rising from beneath the level of the sea. Its occurrence in this situation is striking, as not a single pebble can be

observed in the entire thickness of subjacent beds of sand and clay.

The dip of the marine strata, at the base of Etna, is by no means uniform; on the eastern side, for example, they are sometimes inclined towards the sea, and at others towards the mountain. Near the aqueduct at Adernò, on the southern side, I observed two sections, in quarries not far distant from each other, where beds of clay and yellow sand dipped, in one locality, at an angle of forty-five degrees to the east-south-east, and in the other at a much higher inclination in the opposite direction. These facts would be of small interest, if an attempt had not been made to represent these mixed marine and volcanic deposits which encircle part of the base of Etna, as the outer margin of a so-called 'elevation crater*.'

Near Catania the marine formation, consisting chiefly of volcanic tuff thinly laminated, terminates in a steep inland cliff, or escarpment, which is from six hundred to eight hundred feet in height. A low flat, composed of recent lava and volcanic sand, intervenes between the sea and the base of this escarpment, which may be well seen at Fasano. (*f*, diagram No. 11.)

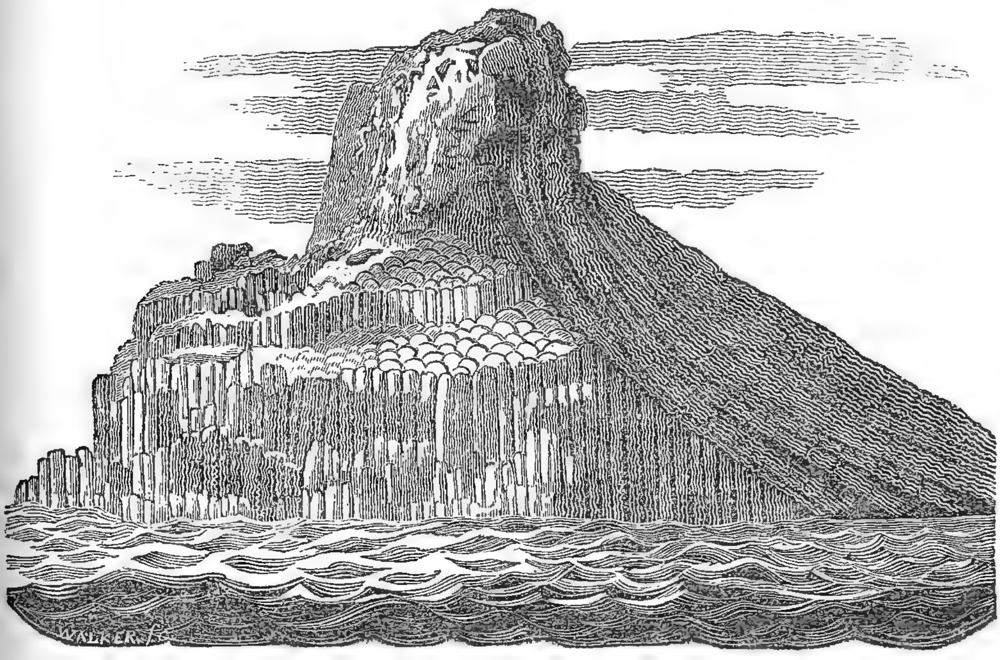
Eastern side of Etna—Bay of Trezza.—Proceeding northwards from Catania, we have opportunities of examining the same sub-Etnean formations laid open more distinctly in the modern sea cliffs, especially in the Bay of Trezza and in the Cyclopian islands (Dei Faraglioni), which may be regarded as the extremity of a promontory severed from the main land. Numerous are the proofs of submarine eruptions of high antiquity in this spot, where the argillaceous and sandy beds have been invaded and intersected by lava, and where those peculiar tufaceous breccias occur which result from ejections of fragmentary matter, projected from a volcanic vent. I observed many angular and hardened fragments of laminated clay (creta), in different states of alteration, between La Trezza and Nizzitta, and in the hills above Aci Castello, a town on the main land contiguous to the Cyclopian isles, which could not be mistaken

* See vol. i. chap. xxii.

by one familiar with Somma and the minor cones of Ischia, for anything but masses thrown out by volcanic explosions. From the tuffs and marls of this district I collected a great variety of marine shells*, almost all of which have been identified with species now inhabiting the Mediteranean, and, for the most part, now frequent on the coast immediately adjacent. Some few of these fossil shells retain part of their colour, which is the same as in their living analogues.

The largest of the Cyclopian islets, or rather rocks, is distant two hundred yards from the land, and is only three hundred yards in circumference, and about two hundred feet in height. The summit and northern sides are formed of a mass of stratified marl (creta), the laminæ of which are occasionally subdivided by thin arenaceous layers. These strata rest on a mass of columnar lava (see wood-cut, No. 14)†, which appears to have forced itself into, and to have heaved up the stratified mass.

No. 14.



View of the Isle of Cyclops in the Bay of Trezza.

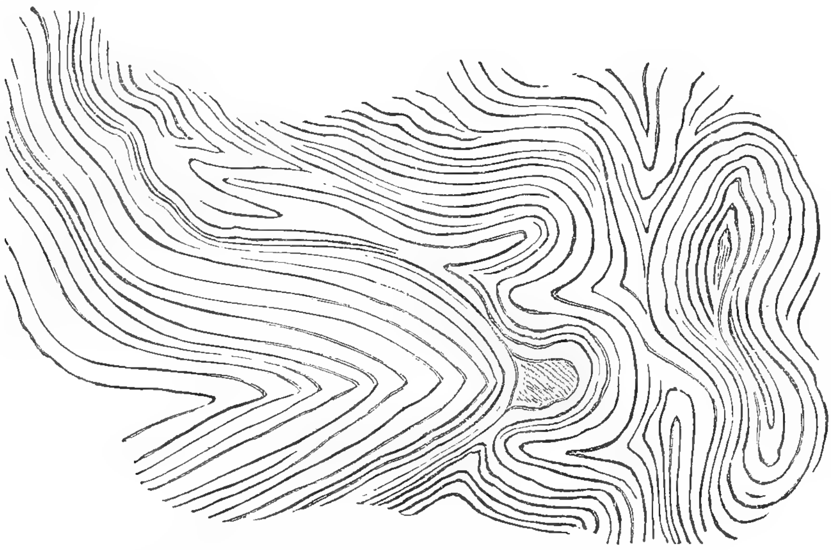
* See, in Appendix No. II., a list, by M. Deshayes, of sixty-five species, which I procured from the hills called Monte Cavalaccio, Rocca di Ferro, and Rocca di Bempolere (or Borgia).

† This cut is from an original drawing by my friend Capt. W. H. Smyth, R.N.

This theory of the intrusion of the basalt is confirmed by the fact, that in some places the clay has been greatly altered, and hardened by the action of heat, and occasionally contorted in the most extraordinary manner, the lamination not having been obliterated, but, on the contrary, rendered much more conspicuous by the indurating process.

The annexed wood-cut (No. 15) is a careful representation of a portion of the altered rock, a few feet square, where the alternate thin laminæ of sand and clay have put on the appearance which we often observe in some of the most contorted of the primary schists.

No. 15.



Contortions in the newer Pliocene strata, Isle of Cyclops.

A great fissure, running from east to west, nearly divides the island into two parts, and lays open its internal structure. In the section thus exhibited, a dike of lava is seen, first cutting through an older mass of lava, and then penetrating the superincumbent tertiary strata. In one locality, the lava ramifies and terminates in thin veins, from a few feet to a few inches in thickness (see diagram No. 16).

No. 16.

Newer Pliocene strata invaded by lava, Isle of Cyclops (horizontal section).

a, Lava. *b*, laminated clay and sand. *c*, the same altered.

The arenaceous laminæ are much hardened at the point of contact, and the clays are converted into siliceous schist. In this island the altered rocks assume a honeycombed structure on their weathered surface, singularly contrasted with the smooth and even outline which the same beds present in their usual soft and yielding state.

The pores of the lava are sometimes coated, or entirely filled, with carbonate of lime, and with a zeolite resembling analcime, which has been called cyclopite. The latter mineral has also been found in small fissures traversing the altered marl, showing that the same cause which introduced the minerals into the cavities of the lava, whether we suppose sublimation or aqueous infiltration, conveyed it also into the open rents of the contiguous sedimentary strata.

Lavas of the Cyclopian Isles not currents from Etna.—The phenomena of the Bay of Trezza are very important, for it is evident that the submarine lavas were produced by eruptions on the spot, an inference which follows not only from the presence of dikes and veins, but from those tuffs above Castello d'Aci, which contain angular fragments of hardened marl, evidently thrown up, together with the sand and scoriæ, by volcanic

explosions. We may, therefore, suppose this volcanic action to have been as independent of the modern vents of Etna, as that which gave rise to the analogous formations in the Val di Noto. It is quite evident that the lavas of the Cyclopian isles are not the lower extremities of currents which flowed down from the highest crater of Etna, or from the region where lateral eruptions are now frequent,—lavas which, after entering the sea, were afterwards upraised into their present position. It is more probable that the basalts of the Bay of Trezza, and those along the southern foot of Etna, at La Motta, Adernò, Paternò, Licodia, and other places, originated in the same sea in which the eruptions of the Val di Noto took place.

There are, however, as we have observed, no sections to prove that the central and oldest parts of Etna repose on similar submarine formations. The modern lavas of the volcano are continually extending their area, and covering, from time to time, a larger portion of the marine strata; but we know not where this operation commenced, so that we cannot demonstrate the posteriority of the whole cone to these newer Pliocene strata.

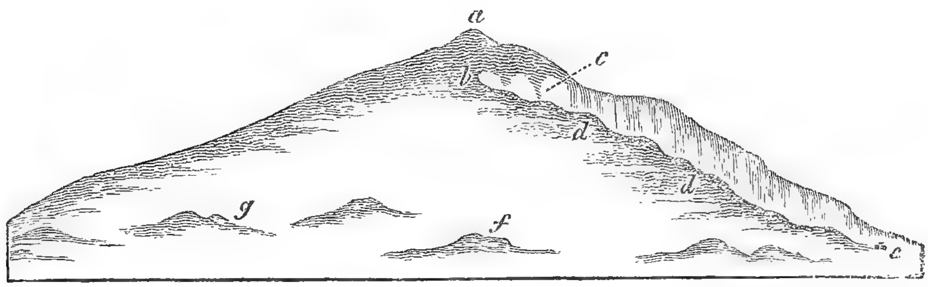
We might imagine that when the volcanos of the Val di Noto were in activity, and when the eruptions of the Bay of Trezza were taking place, Etna already existed as a volcano, the upper part only of the cone projecting above the level of the waters, as in the case of Stromboli at present. By such an hypothesis, we might refer the origin of the older part of Etna to the same period as that of the sedimentary strata and volcanic rocks of the Val di Noto.

But, for our own part, we see no grounds for inclining to such a theory, since we must admit that a sufficient series of ages has elapsed since the limestone of the Val di Noto was deposited, to allow the same to be elevated to the height of from two thousand to three thousand feet, in which case there may also have been sufficient time for the growth of a volcanic pile like Etna, since the newer Pliocene strata now seen at the base of the volcano originated.

INTERNAL STRUCTURE OF THE CONE OF ETNA.

In our first volume we merely described that part of Etna which has been formed during the historical era; an insignificant portion of the whole mass. Nearly all the remainder may be referred to the tertiary period immediately antecedent to the *recent* epoch. We before stated, that the great cone is, in general, of a very symmetrical form, but is broken, on its eastern side, by a deep valley, called the Val del Bove*, which,

No. 17.



Great valley on the east side of Etna.

a, highest cone. *b*, Montagnuola. *c*, Head of Val del Bove. *d*, *d*, Serre del Solfizio. *e*, Zaffarana. *f*, One of the lateral cones. *g*, Monti Rossi.

commencing near the summit of the mountain, descends into the woody region, and is then continued, on one side, by a second and narrower valley, called the Val di Calanna. Below the latter another, named the Val di St. Giacomo, begins,—a long narrow ravine, which is prolonged to the neighbourhood of Zaffarana (*e*, No. 17), on the confines of the fertile region. These natural incisions, into the side of the volcano, are of such

* In the provincial dialect of the peasants called 'Val del Bué,' for here the herdsman

——— 'in reductâ valle *mugientium*
Prospectat errantes greges.—'

Dr. Buckland was, I believe, the first English geologist who examined this valley with attention, and I am indebted to him for having described it to me, before my visit to Sicily, as more worthy of attention than any single spot in that island, or perhaps in Europe. I have already stated, that the view of this valley, which I have given in the frontispiece of the second volume, does not pretend to convey any idea of the grandeur of the scene.

depth that they expose to view a great part of the structure of the entire mass, which, in the Val del Bove, is laid open to the depth of from four thousand to five thousand feet from the summit of Etna. The geologist thus enjoys an opportunity of ascertaining how far the internal conformation of the cone corresponds with what he might have anticipated as the result of that mode of increase which has been witnessed during the historical era.

It is clear, from what we before said of the gradual manner in which the principal cone increases, partly by streams of lava and showers of volcanic ashes ejected from the summit, partly by the throwing up of minor hills and the issuing of lava-currents on the flanks of the mountain, that the whole cone must consist of a series of cones enveloping others, the regularity of each being only interrupted by the interference of the lateral volcanos.

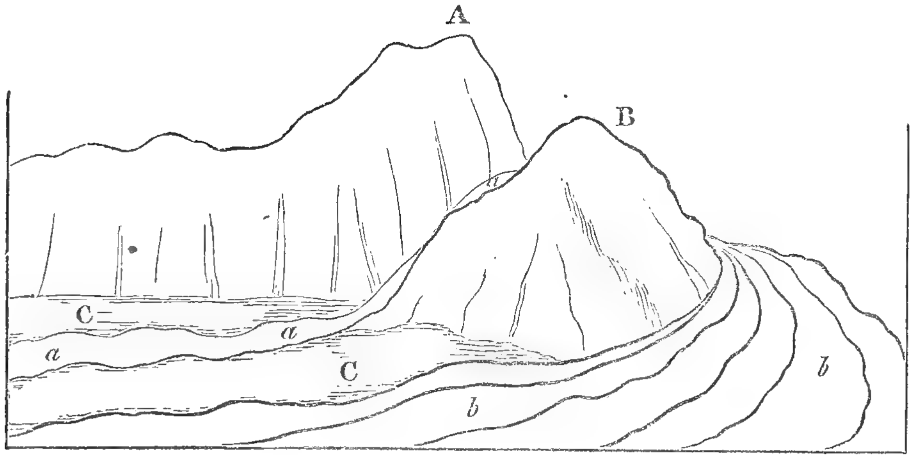
We might, therefore, have anticipated that a section of Etna, as exposed in a ravine which should begin near the summit and extend nearly to the sea, would correspond very closely to the section of the ancient Vesuvius, commencing with the escarpment of Somma, and ending with the Fossa Grande; but with this difference, that where the ravine intersects the woody region of Etna, indications must appear of changes brought about by lateral eruptions. Now the section before alluded to, which can be traced from the head of the Val del Bove to the inferior borders of the woody region, fully answers such expectations. We find, almost everywhere, a series of layers of tuff and breccia interstratified with lavas, which slope gently to the sea, at an angle of from twenty to thirty degrees; and as we rise to the parallel of the zone of lateral eruptions, and still more as we approach the summit, we discover indications of disturbances, occasioned by the passage of lava from below, and the successive inhumation of lateral cones.

Val di Calanna.—On leaving Zaffarana, on the borders of the fertile region, we enter the ravine-like valley of St. Giacomo, and see on the north side, or on our right as we ascend,

rising ground composed of the modern lavas of Etna. On our left, a lofty cliff, wherein a regular series of beds is exhibited, composed of tuffs and lavas, descending with a gentle inclination towards the sea. In this lower part of the section there are no intersecting dikes, nor any signs of minor cones interfering with the regular slope of the alternating volcanic products. If we then pass upwards through a defile, called the 'Portello di Calanna,' we enter a second valley, that of Calanna, resembling the ravine before mentioned, but wider and much deeper. Here again we find, on our right, many currents of modern lava, piled one upon the other, and on our left a continuation of our former section, in a perpendicular cliff from four hundred to five hundred feet high. As this lofty wall sweeps in a curve, it has very much the appearance of the escarpment which Somma presents towards Vesuvius, and this resemblance is increased by the occurrence of two or three vertical dikes which traverse the gently-inclined volcanic beds. When I first beheld this precipice, I fancied that I had entered a lateral crater, but was soon undeceived, by discovering that on all sides, both at the head of the valley, in the hill of Zocolaro, and at its side and lower extremity, the dip of the beds was always in the same direction, all slanting to the east, or towards the sea, instead of sloping to the north, east, and south, as would have been the case had they constituted three walls of an ancient crater.

It is not difficult to explain how the valleys of St. Giacomo and Calanna originated, when once the line of lofty precipices on the north side of them had been formed. Many lava-currents flowing down successively from the higher regions of Etna, along the foot of a great escarpment of volcanic rock, have at length been turned by a promontory at the head of the valley of Calanna, which runs out at right angles to the great line of precipices. This promontory consists of the hills called Zocolaro and Calanna, and of a ridge of inferior height which connects them. (See diagram No. 18.)

No. 18.



A, Zocolaro. B, Monte di Calanna.
C, Plain at the head of the Valley of Calanna.
a, Lava of 1819 descending the precipice and flowing through the valley.
b, Lavas of 1811 and 1819 flowing round the hill of Calanna.

The flows of melted matter have been deflected from their course by this projecting mass, just as a tidal current, after setting against a line of sea-cliffs, is often thrown off into a new direction by some rocky headland.

Lava-streams, it is well known, become solid externally, even while yet in motion, and their sides may be compared to two rocky walls, which are sometimes inclined at an angle of forty-five degrees. When such streams descend a considerable slope at the base of a line of precipices, and are turned from their course by a projecting rock, they move right onwards in a new direction, so as to leave a considerable space (as in the Valley of Calanna) between them and the cliffs which may be continuous below the point of deflection.

It happened in 1811 and 1819, that the flows of lava overtopped the ridge intervening between the hills of Zocolaro and Calanna, so that they fell in a cascade over a lofty precipice, and began to fill up the valley. (See letter *a*, diagram No. 18.)

The narrow cavity of St. Giacomo will admit of an explanation precisely similar to that already offered for Calanna.

Val del Bove.—After passing up through the defile, called the 'Rocca di Calanna,' we enter a third valley of truly magnificent dimensions—the Val del Bove—a vast amphitheatre four or five miles in diameter, surrounded by nearly vertical precipices, varying from one thousand to above three thousand feet in height, the loftiest being at the upper end, and the height gradually diminishing on both sides. The feature which first strikes the geologist as distinguishing this valley from those before mentioned, is the prodigious multitudes of vertical dikes, which are seen in all directions traversing the volcanic beds. The circular form of this great chasm, and the occurrence of these countless dikes, amounting perhaps to several thousands in number, so forcibly recalled to my mind the phenomena of the Atrio del Cavallo, on Vesuvius, that I imagined once more that I had entered a vast crater, on a scale as far exceeding that of Somma, as Etna surpasses Vesuvius in magnitude.

But having already been deceived in regard to the crescent-shaped precipice of the valley of Calanna, I began attentively to explore the different sides of the great amphitheatre, in order to satisfy myself whether the semicircular wall of the Val del Bove had ever formed the boundary of a crater, and whether the beds had the same quâquâ-versal dip which is so beautifully exhibited in the escarpment of Somma. If the supposed analogy between Somma and the Val del Bove should hold true, the tuffs and lavas, at the head of the valley, would dip to the west, those on the north side towards the north, and those on the southern side to the south. But such I did not find to be the inclination of the beds; they all dip towards the sea, or nearly east, as was before seen to be the case in the Valley of Calanna.

There are undoubtedly exceptions to this general rule, which might deceive a geologist who was strongly prepossessed with a belief that he had discovered the hollow of an ancient crater. It is evident that, wherever lateral cones are intersected in the precipices, a series of tuffs and lavas, very similar to those which

enter into the structure of the great cone, will be seen dipping at a much more rapid angle.

The lavas and tuffs, which have conformed to the sides of Etna, dip at angles of from fifteen to twenty-five degrees, while the slope of the lateral cones is from thirty-five to fifty degrees. Now, wherever we meet with sections of these buried cones in the precipices bordering the Val del Bove, (and they are frequent in the cliffs called the Serre del Solfizio, and in those near the head of the valley not far from the rock of Musara,) we find the beds dipping at high angles and inclined in various directions*.

Scenery of the Val del Bove.—Without entering at present into any further discussions respecting the origin of the Val del Bove, we shall proceed to describe some of its most remarkable features. Let the reader picture to himself a large amphitheatre, five miles in diameter, and surrounded on three sides by precipices from two thousand to three thousand feet in height. If he has beheld that most picturesque scene in the chain of the Pyrenees, the celebrated 'cirque of Gavarnie,' he may form some conception of the magnificent circle of precipitous rocks which inclose, on three sides, the great plain of the Val del Bove. This plain has been deluged by repeated streams of lava, and although it appears almost level when viewed from a distance, it is, in fact, more uneven than the surface of the most tempestuous sea. Besides the minor irregularities of the lava, the valley is in one part interrupted by a ridge of rocks, two of which, Musara and Capra, are very prominent. It can hardly be said that they

——— 'like giants stand
To sentinel enchanted land;'

for although, like the Trosachs, they are of gigantic dimen-

* I perceive that Professor Hoffmann, who visited the Val del Bove after me (in January, 1831), has speculated on its structure as corresponding to that of the so-called elevation craters, which hypothesis would require that there should be a quâquâ-versal dip, such as I have above alluded to. I can only account for this difference of opinion, by supposing the Professor to have overlooked the phenomena of the buried cones.—Archiv für Mineralogie, &c. Berlin, 1831.

sions, and appear almost isolated as seen from many points, yet the stern and severe grandeur of the scenery which they adorn is not such as would be selected by a poet for a vale of enchantment. The character of the scene would accord far better with Milton's picture of the infernal world; and if we imagine ourselves to behold in motion, in the darkness of the night, one of those fiery currents, which have so often traversed the great valley, we may well recall

——— 'yon dreary plain, forlorn and wild,
The seat of desolation, void of light
Save what the glimmering of these vivid flames
Cast pale and dreadful.'

The face of the precipices already mentioned is broken in the most picturesque manner by the vertical walls of lava which traverse them. These masses usually stand out in relief, are exceedingly diversified in form, and often of immense altitude. In the autumn, their black outline may often be seen relieved by clouds of fleecy vapour which settle behind them, and do not disperse until midday, continuing to fill the valley while the sun is shining on every other part of Sicily, and on the higher regions of Etna.

As soon as the vapours begin to rise, the changes of scene are varied in the highest degree, different rocks being unveiled and hidden by turns, and the summit of Etna often breaking through the clouds for a moment with its dazzling snows, and being then as suddenly withdrawn from the view.

An unusual silence prevails, for there are no torrents dashing from the rocks, nor any movement of running water in this valley, such as may almost invariably be heard in mountainous regions. Every drop of water that falls from the heavens, or flows from the melting ice and snow, is instantly absorbed by the porous lava; and such is the dearth of springs, that the herdsman is compelled to supply his flocks, during the hot season, from stores of snow laid up in hollows of the mountain during winter.

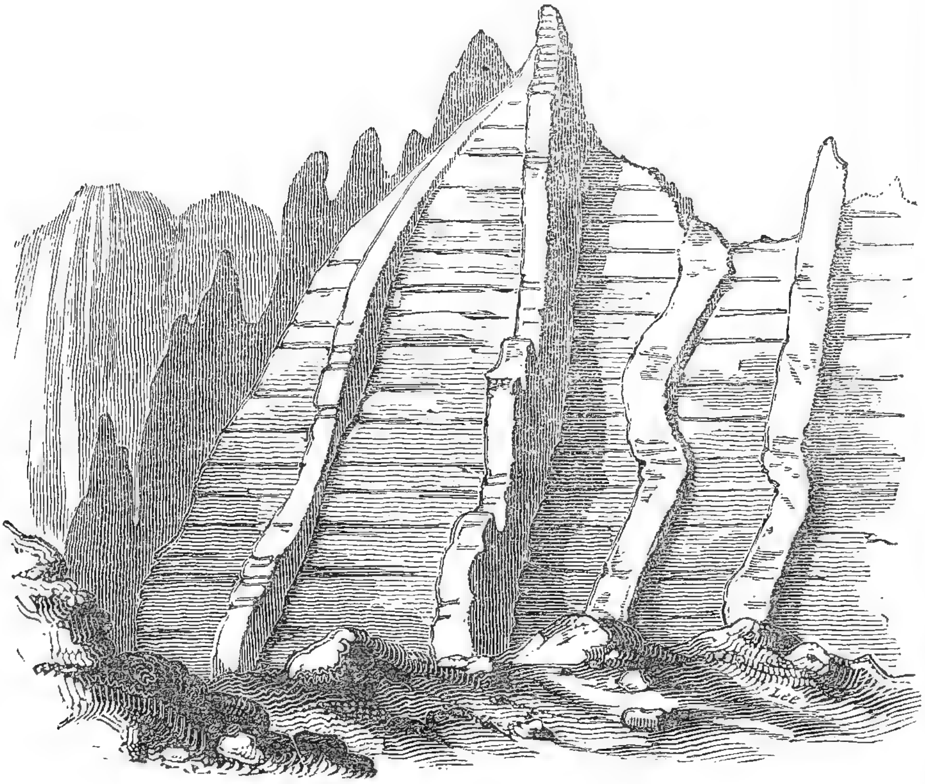
The strips of green herbage and forest-land, which have

here and there escaped the burning lavas, serve, by contrast, to heighten the desolation of the scene. When I visited the valley, nine years after the eruption of 1819, I saw hundreds of trees, or rather the white skeletons of trees, on the borders of the black lava, the trunks and branches being all leafless, and deprived of their bark by the scorching heat emitted from the melted rock ; an image recalling those beautiful lines—

—— 'As when heaven's fire
Hath scath'd the forest oaks, or mountain pines,
With singed top their stately growth, though bare,
Stands on the blasted heath.'

Form, composition, and origin of the Dikes.—But without indulging the imagination any longer in descriptions of scenery, we may observe, that the dikes before mentioned form unquestionably the most interesting geological phenomenon in the Val del Bove.

No. 19.

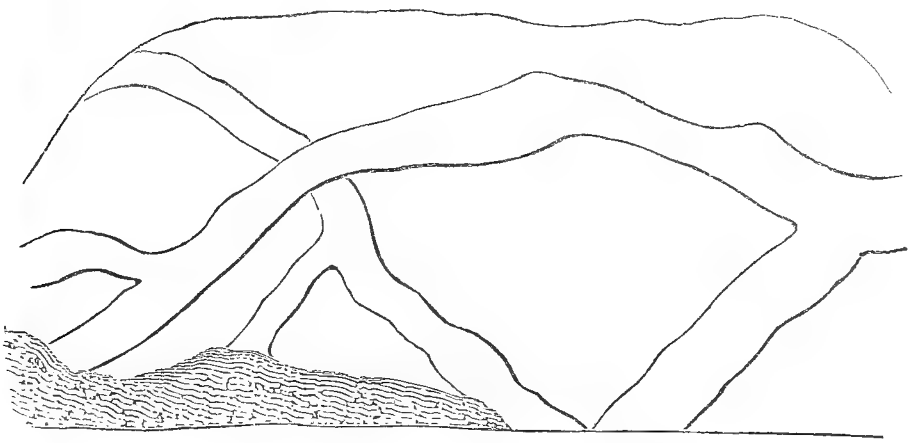


Dikes at the base of the Serre del Solfizio, Etna.

Some of these are composed of trachyte, others oi compact

blue basalt with olivine. They vary in breadth from two to twenty feet and upwards, and usually project from the face of the cliffs, as represented in the annexed drawing (No. 19). They consist of harder materials than the strata which they traverse, and therefore waste away less rapidly under the influence of that repeated congelation and thawing to which the rocks in this zone of Etna are exposed. The dikes are, for the most part, vertical, but sometimes they run in a tortuous course through the tuffs and breccias, as represented in diagram, No. 20. In the escarpment of Somma where, as we

No. 20.



Veins of Lava. Punto di Guimento.

before observed, similar walls of lava cut through alternating beds of sand and scoriæ, a coating of coal-black rock, approaching in its nature and appearance to pitch-stone, is seen at the contact of the dike with the intersected beds. I did not observe such parting layers at the junction of the Etnean dikes which I examined, but they may perhaps be discoverable.

The geographical position of these dikes is most interesting, as they occur in that zone of the mountain where lateral eruptions are frequent; whereas, in the valley of Calanna, which is below that parallel, and in a region where lateral eruptions are extremely rare, scarcely any dikes are seen, and none whatever still lower in the valley of St. Giacomo. This is precisely what we should have expected, if we consider the vertical fissures now filled with rock to have been the feeders of lateral

cones, or, in other words, the channels which gave passage to the lava-currents and scoriæ that have issued from vents in the forest-zone.

Some fissures may have been filled from above, but I did not see any which, by terminating downwards, gave proof of such an origin. Almost all the isolated masses in the Val del Bove, such as Capra, Musara, and others, are traversed by dikes, and may, perhaps, have partly owed their preservation to that circumstance, if at least the action of occasional floods has been one of the destroying causes in the Val del Bove; for there is nothing which affords so much protection to a mass of strata against the undermining action of running water, as a perpendicular dike of hard rock.

In the accompanying drawing (No. 21) the flowing of the

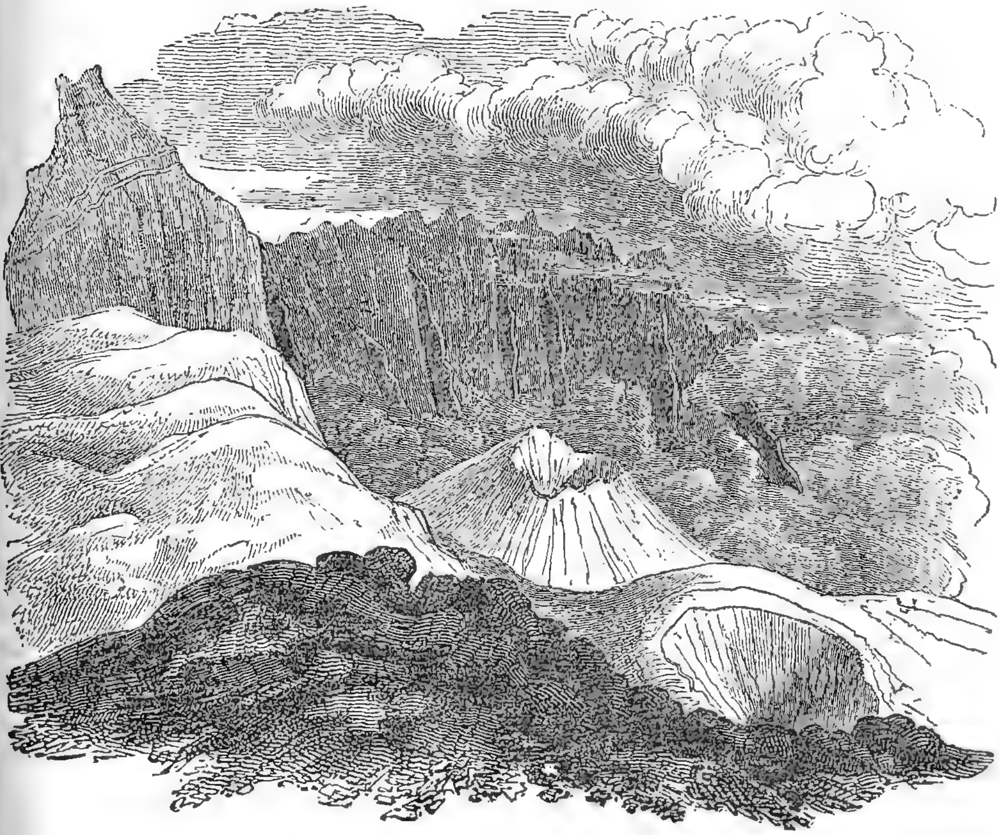
No. 21.

View of the rocks Finochio, Capra, and Musara, Val del Bove.

lavas of 1811 and 1819, between the rocks Finochio, Capra, and Musara, is represented. The height of the two last-mentioned isolated masses has been much diminished by the elevation of their base, caused by these currents. They may, perhaps, be the remnants of cones, which existed before the Val del Bove was formed, and may hereafter be once more buried by the lavas that are now accumulating in the valley.

From no point of view are the dikes more conspicuous than from the summit of the highest cone of Etna; a view of some of them are given in the annexed drawing*.

No. 22.



View from the summit of Etna into the Val del Bove.

The small cone and crater immediately below were among those formed during the eruptions of 1810 *and* 1811.

Lavas and breccias.—In regard to the volcanic masses which are intersected by dikes in the Val del Bove, they consist, in great part, of graystone lavas, of an intermediate character between basalt and trachyte, and partly of the trachytic varieties of lava. Beds of scoriæ and sand, also, are very numerous, alternating with breccias formed of angular blocks of igneous rock. It is possible that some of the breccias may be referred to aqueous causes, as we have before seen that great

* This drawing is part of a panoramic sketch which I made from the summit of the cone, December 1st, 1828, when every part of Etna was free from clouds except the Val del Bove.

floods do occasionally sweep down the flanks of Etna when eruptions take place in winter, and when the snows are melted by lava.

Many of the angular fragments may have been thrown out by volcanic explosions, which, falling on the hardened surface of moving lava-currents, may have been carried to a considerable distance. It may also happen, that when lava advances very slowly, in the manner of the flow of 1819, described in the first volume*, the angular masses resulting from the frequent breaking of the mass as it rolls over upon itself, may produce these breccias. It is at least certain, that the upper portion of the lava-currents of 1811 and 1819, now consist of angular masses to the depth of many yards.

D'Aubuisson has compared the surface of one of the ancient lavas of Auvergne to that of a river suddenly frozen over by the stoppage of immense fragments of drift-ice, a description perfectly applicable to these modern Etnean flows.

* Chap. xxi.

CHAPTER VIII.

Speculations on the origin of the Val del Bove on Etna—Subsidences—Antiquity of the cone of Etna—Mode of computing the age of volcanos—Their growth analogous to that of exogenous trees—Period required for the production of the lateral cones of Etna—Whether signs of Diluvial Waves are observable on Etna.

ORIGIN OF THE VAL DEL BOVE.

Before concluding our observations on the cone of Etna, the structure of which was considered in the last chapter, we desire to call the reader's attention to several questions:—first, in regard to the probable origin of the great valley already described; secondly, whether any estimate can be made of the length of the period required for the accumulation of the great cone; and, thirdly, whether there are any signs on the surface of the older parts of the mountain, of those devastating waves which, according to the theories of some geologists, have swept again and again over our continents.

Origin of the Val del Bove.—We explained our reasons in the last chapter for not assenting to the opinion, that the great cavity on the eastern side of Etna was the hollow of an immense crater, from which the volcanic masses of the surrounding walls were produced. On the other hand, we think it impossible to ascribe the valley to the action of running water alone; for if it had been excavated exclusively by that power, its depth would have increased in the descent; whereas, on the contrary, the precipices are most lofty at the upper extremity, and diminish gradually on approaching the lower region of the volcano.

The structure of the surrounding walls is such as we should expect to see exhibited on any other side of Etna, if a cavity of equal depth should be caused, whether by subsidence, or by the blowing up of part of the flanks of the volcano, or by either of these causes co-operating with the removing action of running water.

It is recorded, as we have already seen in our history of earthquakes, that in the year 1772 an immense subsidence took place on Papandayang, the largest volcano in the island of Java, and that, during the catastrophe, an extent of ground, *fifteen miles in length and six in breadth,* gave way, so that no less than forty villages were engulphed, and the cone lost no less than four thousand feet of its height *.

Now we might imagine a similar event, or a series of subsidences to have formerly occurred on the eastern side of Etna, although such catastrophes have not been witnessed in modern times, or only on a very trifling scale. A narrow ravine, about a mile long, twenty feet wide, and from twenty to thirty-six in depth, has been formed, within the historical era, on the flanks of the volcano, near the town of Mascalucia; and a small circular tract, called the Cisterna, near the summit, sank down in the year 1792, to the depth of about forty feet, and left on all sides of the chasm a vertical section of the beds, exactly resembling those which are seen in the precipices of the Val del Bove. At some remote periods, therefore, we might suppose more extensive portions of the mountain to have fallen in during great earthquakes.

But some geologists will, perhaps, incline to the opinion, that the removed mass was blown up by paroxysmal explosions, such as that which, in the year 79, destroyed the ancient cone of Vesuvius, and gave rise to the escarpment of Somma. The Val del Bove, it will be remembered, lies within the zone of lateral eruptions, so that a repetition of volcanic explosions might have taken place, after which the action of running water may have contributed powerfully to degrade the rocks, and to transport the materials to the sea. We have before alluded to the effects of a violent flood, which swept through the Val del Bove in the year 1755, when a fiery torrent of lava had suddenly overflowed a great depth of snow in winter †.

In the present imperfect state of our knowledge of the his-

* Vol. i. chap. xxv.

† See vol. i. chap. xxi.

tory of volcanos, we have some difficulty in deciding on the relative probability of these hypotheses; but if we embrace the theory of explosions from below, the cavity would not constitute a *crater* in the ordinary acceptation of that term, still less would it accord with the notion of the so-called 'elevation craters.'

ANTIQUITY OF THE CONE OF ETNA.

We have stated in a former volume, that confined notions in regard to the quantity of past time, have tended, more than any other prepossessions, to retard the progress of sound theoretical views in Geology; the inadequacy of our conceptions of the earth's antiquity having cramped the freedom of our speculations in this science, very much in the same way as a belief in the existence of a vaulted firmament once retarded the progress of astronomy. It was not until Descartes assumed the indefinite extent of the celestial spaces, and removed the supposed boundaries of the universe, that just opinions began to be entertained of the relative distances of the heavenly bodies; and until we habituate ourselves to contemplate the possibility of an indefinite lapse of ages having been comprised within each of the more modern periods of the earth's history, we shall be in danger of forming most erroneous and partial views in Geology.

Mode of computing the age of volcanos.—If history had bequeathed to us a faithful record of the eruptions of Etna, and a hundred other of the principal active volcanos of the globe, during the last three thousand years,—if we had an exact account of the volume of lava and matter ejected during that period, and the times of their production,—we might, perhaps, be able to form a correct estimate of the average rate of the growth of a volcanic cone. For we might obtain a mean result from the comparison of the eruptions of so great a number of vents, however irregular might be the development of the igneous action in any one of them, if contemplated singly during a brief period.

It would be necessary to balance protracted periods of inaction against the occasional outburst of paroxysmal explosions. Sometimes we should have evidence of a repose of seventeen centuries, like that which was interposed in Ischia, between the end of the fourth century, B. C., and the beginning of the fourteenth century of our era *. Occasionally a tremendous eruption, like that of Jorullo, would be recorded, giving rise, at once, to a considerable mountain.

If we desire to approximate to the age of a cone such as Etna, we ought first to obtain some data in regard to the thickness of matter which has been added during the historical era, and then endeavour to estimate the time required for the accumulation of such alternating lavas and beds of sand and scoriæ as are superimposed upon each other in the Val del Bove; afterwards we should try to deduce, from observations on other volcanos, the more or less rapid increase of burning mountains in all the different stages of their growth.

Mode of increase of volcanos analogous to that of exogenous trees.—There is a considerable analogy between the mode of increase of a volcanic cone and that of trees of *exogenous* growth. These trees augment, both in height and diameter, by the successive application externally of cone upon cone of new ligneous matter, so that if we make a transverse section near the base of the trunk, we intersect a much greater number of layers than nearer to the summit. When branches occasionally shoot out from the trunk they first pierce the bark, and then, after growing to a certain size, if they chance to be broken off, they may become inclosed in the body of the tree, as it augments in size, forming knots in the wood, which are themselves composed of layers of ligneous matter, cone within cone.

In like manner a volcanic mountain, as we have seen, consists of a succession of conical masses enveloping others, while lateral cones, having a similar internal structure, often project, in the first instance, like branches from the surface of the main cone, and then becoming buried again, are hidden like the knots of a tree.

* See vol. i. chap. xix.

We can ascertain the age of an oak or pine, by counting the number of concentric rings of annual growth, seen in a transverse section near the base, so that we may know the date at which the seedling began to vegetate. The Baobab-tree of Senegal (*Adansonia digitata*) is supposed to exceed almost any other in longevity; Adanson inferred that one which he measured, and found to be thirty feet in diameter, had attained the age of 5150 years. Having made an incision to a certain depth, he first counted three hundred rings of annual growth, and observed what thickness the tree had gained in that period. The average rate of growth of younger trees, of the same species, was then ascertained, and the calculation, made according to a supposed mean rate of increase. De Candolle considers it not improbable, that the celebrated Taxodium of Chapultepec, in Mexico (*Cupressus disticha*, Linn.), which is one hundred and seventeen feet in circumference, may be still more aged*.

It is, however, impossible, until more data are collected respecting the average intensity of the volcanic action, to make anything like an approximation to the age of a cone like Etna, because, in this case, the successive envelopes of lava and scoriæ are not continuous, like the layers of wood in a tree, and afford us no definite measure of time. Each conical envelope is made up of a great number of distinct lava-currents and showers of sand and scoriæ, differing in quantity, and which may have been accumulated in unequal periods of time. Yet we cannot fail to form the most exalted conception of the antiquity of this mountain, when we consider that its base is about ninety miles in circumference; so that it would require ninety flows of lava, each a mile in breadth at their termination, to raise the present foot of the volcano as much as the average height of one lava-current.

There are no records within the historical era which lead to the opinion, that the altitude of Etna has materially varied

* On the Longevity of Trees, Bibliot. Univ., May, 1831.

within the last two thousand years. Of the eighty most conspicuous minor cones which adorn its flanks, only one of the largest, Monti Rossi, has been produced within the times of authentic history. Even this hill, thrown up in the year 1669, although 450 feet in height, only ranks as a cone of second magnitude. Monte Minardo, near Bronte, rises, even now, to the height of 750 feet, although its base has been elevated by more modern lavas and ejections. The dimensions of these larger cones appear to bear testimony to *paroxysms* of volcanic activity, after which we may conclude, from analogy, that the fires of Etna remained dormant for many years—since nearly a century of rest has sometimes followed a violent eruption in the historical era. It must also be remembered, that of the small number of eruptions which occur in a century, one only is estimated to issue from the summit of Etna for every two that proceed from the sides. Nor do all the lateral eruptions give rise to such cones as would be enumerated amongst the smallest of the eighty hills above enumerated; some produce merely insignificant monticules, soon destined to be buried, as we before explained.

How many years then must we not suppose to have been expended in the formation of the eighty cones? It is difficult to imagine that a fourth part of them have originated during the last thirty centuries. But if we conjecture the whole of them to have been formed in twelve thousand years, how inconsiderable an era would this portion of time constitute in the history of the volcano! If we could strip off from Etna all the lateral monticules now visible, together with the lavas and scoriæ that have been poured out from them, and from the highest crater, during the period of their growth, the diminution of the entire mass would be extremely slight! Etna might lose, perhaps, several miles in diameter at its base, and some hundreds of feet in elevation, but it would still be the loftiest of Sicilian mountains, studded with other cones, which would be recalled, as it were, into existence by the removal of the rocks under which they are now buried.

There seems nothing in the deep sections of the Val del Bove, to indicate that the lava currents of remote periods were greater in volume than those of modern times; and there are abundant proofs that the countless beds of solid rock and scoriæ were accumulated, as now, in succession. On the grounds, therefore, already explained, we must infer that a mass, eight thousand or nine thousand feet in thickness, must have required an immense series of ages anterior to our historical periods, for its growth; yet the whole must be regarded as the product of a modern portion of the newer Pliocene epoch. Such, at least, is the conclusion that we draw from the geological data already detailed, which show that the oldest parts of the mountain, if not of posterior date to the marine strata which are visible around its base, were at least of coeval origin.

Whether signs of Diluvial Waves are observable on Etna.—Some geologists contend, that the sudden elevation of large continents from beneath the waters of the sea, have again and again produced waves which have swept over vast regions of the earth, and left enormous rolled blocks strewed over the surface*. That there are signs of local floods of extreme violence, on various parts of the surface of the dry land, is incontrovertible, and in the former volumes we have pointed out causes which must for ever continue to give rise to such phenomena; but for the proofs of these general cataclysms we have searched in vain. It is clear that no devastating wave has passed over the forest zone of Etna, since any of the lateral cones before mentioned were thrown up; for none of these heaps of loose sand and scoriæ could have resisted for a moment the denuding action of a violent flood.

To some, perhaps, it may appear that hills of such incoherent materials cannot be of immense antiquity, because the mere action of the atmosphere must, in the course of several thousand years, have obliterated their original forms. But there is no weight in this objection, for the older hills are covered with

* Sedgwick, Anniv. Address to the Geol. Soc., p. 35. Feb. 1831.

trees and herbage, which protect them from waste; and in regard to the newer ones, such is the porosity of their component materials, that the rain which falls upon them is instantly absorbed, and, for the same reason that the rivers on Etna have a subterranean course, there are none descending the sides of the minor cones.

No sensible alteration has been observed in the form of these cones since the earliest periods of which there are memorials; and we see no reason for anticipating, that in the course of the next ten thousand or twenty thousand years they will undergo any great alteration in their appearance, unless they should be shattered by earthquakes, or covered by volcanic ejections.

We shall afterwards point out, that, in other parts of Europe, similar loose cones of scoriæ, which we believe to be of higher antiquity than the whole mass of Etna, stand uninjured at inferior elevations above the level of the sea.

CHAPTER IX.

Origin of the newer Pliocene strata of Sicily—Growth of submarine formations gradual—Rise of the same above the level of the sea probably caused by subterranean lava—Igneous newer Pliocene rocks, formed at great depths, exceed in volume the lavas of Etna—Probable structure of these recent subterranean rocks—Changes which they may have superinduced upon strata in contact—Alterations of the surface during and since the emergence of the newer Pliocene strata—Forms of the Sicilian valleys—Sea cliffs—Proofs of successive elevation—Why the valleys in the newer Pliocene districts correspond in form to those in regions of higher antiquity—Migrations of animals and plants since the emergence of the newer Pliocene strata—Some species newer than the stations they inhabit.—Recapitulation.

ORIGIN OF THE NEWER PLIOCENE STRATA OF SICILY.

HAVING in the last two chapters described the tertiary formations of the Val di Noto and Valdemone, both igneous and aqueous, we shall now proceed more fully to consider their origin, and the manner in which they may be supposed to have assumed their present position. The consideration of this subject may be naturally divided into three parts: first, we shall inquire in what manner the submarine formations were accumulated beneath the waters; secondly, whether they emerged slowly or suddenly, and what modifications in the earth's crust, at considerable depths below the surface, may be indicated by their rise; thirdly, the mutations which the surface and its inhabitants have undergone during and since the period of emergence.

Growth of Submarine formations.—First, then, we are to inquire in what manner the subaqueous masses, whether volcanic or sedimentary, may have been formed. On this subject we have but few observations to make, for by reference to our former volumes, the reader will learn how a single stratum, whether of sand, clay, or limestone, may be thrown down at the bottom of the sea, and how shells and other organic remains

may become imbedded therein. He will also understand how one sheet of lava, or bed of scoriæ and volcanic sand, may be spread out over a wide area, and how, at a subsequent period, a second bed of sand, clay, or limestone, or a second lava-stream may be superimposed, so that in the lapse of ages a mountain mass may be produced.

It is enough that we should behold a single course of bricks or stones laid by the mason upon another, in order to comprehend how a massive edifice, such as the Colosseum at Rome, was erected; and we can have no difficulty in conceiving that a sea, three hundred or four hundred fathoms deep, might be filled up by sediment and lava, provided we admit an indefinite lapse of ages for the accumulation of the materials.

The sedimentary and volcanic masses of the newer Pliocene era, which, in the Val di Noto, attain the thickness of two thousand feet, are subdivided into a vast number of strata and lava-streams, each of which were originally formed on the subaqueous surface, just as the tuffs and lavas whereof sections are laid open in the Val del Bove, were each in their turn external additions to the Etnean cone.

It is also clear, that before any part of the mass of submarine origin began to rise above the waters, the uppermost stratum of the whole must have been deposited; so that if the date of the origin of these masses be comparatively recent, still more so is the period of their rise above the level of the sea.

Subaqueous formations how raised.—In what manner, then, and by what agency, did this rise of the subaqueous formations take place? We have seen that since the commencement of the present century, an immense tract of country in Cutch, more than fifty miles long and sixteen broad, was permanently upraised to the height of ten feet above its former position, and the earthquake which accompanied this wonderful variation of level, is reported to have terminated by a volcanic eruption at Bhooi. We have also seen*, that when the Monte Nuovo was thrown up, in the year 1538, a large fissure ap-

* Vol. i. chap. xix.

proached the small town of Tripergola, emitting a vivid light, and throwing out ignited sand and scoriæ. At length this opening reached a shallow part of the sea close to the shore, and then widened into a large chasm, out of which were discharged blocks of lava, pumice, and ashes. But no current of melted matter flowed from the orifice, although it is perfectly evident that lava existed below in a fluid state, since so many portions of it were cast up in the form of scoriæ into the air. We have shown that the coast near Puzzuoli rose, at that time, to the height of more than twenty feet above its former level, and that it has remained permanently upheaved to this day *.

On a review of the whole phenomena, it appears most probable that the elevated country was forced upwards by lava which did not escape, but which, after causing violent earthquakes, during several preceding months, produced at length a fissure from whence it discharged gaseous fluids, together with sand and scoriæ. The intruded mass then cooled down at a certain distance below the uplifted surface, and constituted a solid and permanent foundation.

If an habitual vent had previously existed near Puzzuoli, such as we may suppose to remain always open in the principal ducts of Vesuvius or Etna, the lava might, perhaps, have flowed over upon the surface, instead of heaving upwards the superficial strata. In that case, there might have been the same conversion of sea into land, the only difference being, that the lava would have been uppermost, instead of the tufaceous strata containing shells, now seen in the plain of La Starza, and on the site of the Temple of Serapis.

Subterranean lava the upheaving cause.—The only feasible theory, indeed, that has yet been proposed, respecting the causes of the permanent rise of the bed of the sea, is that which refers the phenomenon to the generation of subterranean lava. We have stated, in the first volume, that the regions now habitually convulsed by earthquakes, include within them the site of all the active volcanos. We know that the expan-

* Vol. i. chap. xxv.

sive force of volcanic heat is sufficiently great to overcome the resistance of columns of lava, several miles or leagues in height, forcing them up from great depths, and causing the fluid matter to flow out upon the surface. To imagine, therefore, that this same power, which is so frequently exerted in different parts of the globe, should occasionally propel a column of lava to a considerable height, yet be unable to force it through the superincumbent rocks, is quite natural.

Whenever the superimposed masses happen to be of a yielding and elastic nature, they will bend, and instead of breaking, so as to afford an escape to the melted matter through a fissure, they will allow it to accumulate in large quantities beneath the surface, sometimes in amorphous masses, and sometimes in horizontal sheets. So long as such sheets of matter retain their fluidity, and communicate with the column of lava which is still urged upwards, they must exert an enormous hydrostatic pressure on the overlying mass, tending to elevate it, and an equal force on the subjacent beds pressing them down, and probably rendering them more compact. If we consider how great is the volume of lava that sometimes flows out on the surface from volcanic vents, we must expect that it will produce great changes of level so often as its escape is impeded.

Let us only reflect on the magnitude of Iceland, an island two hundred and sixty miles long by two hundred in breadth, and which rises, at some points, to the height of six thousand feet above the level of the sea. Nearly the entire mass is represented to be of volcanic origin; but even if we suppose some parts to consist of aqueous deposits, still that portion may be more than compensated by the great volume of lava which must have been poured out upon the bottom of the surrounding sea during the growth of the entire island; for we know that submarine eruptions have been considerable near the coast during the historical era. Now if the whole of this lava had been prevented from reaching the surface, by the weight and tenacity of certain overlying rocks, it might have given rise to

the gradual elevation of a tract of land nearly as large as Iceland. We say *nearly*, because the lava which cooled down beneath the surface, and under considerable pressure, would be more compact than the same when poured out in the open air, or in a sea of moderate depth, or shot up into the atmosphere by the explosive force of elastic vapours, and thus converted into sand and scoriæ.

According to this theory, we must suppose the action of the upheaving power to be intermittent, and, like ordinary volcanic eruptions, to be reiterated again and again in the same region, at unequal intervals of time and with unequal degrees of force.

If we follow this train of induction, which appears so easy and natural, to what important conclusions are we led! The reader will bear in mind that the tertiary strata have attained in the central parts of Sicily, as at Castrogiovanni, for example, an elevation of about three thousand feet above the level of the sea, and a height of from fifty to two thousand feet in different parts of the Val di Noto. In this country, therefore, we must suppose a solid support of igneous rock to have been successively introduced into part of the earth's crust immediately subjacent, equal in volume to the upraised tract, and this generation of subterranean rock must have taken place during the latter part of the newer Pliocene period. The dimensions of the Etnean cone shrink into insignificance, in comparison to the volume of this subterranean lava; and, however staggering the inference might at first appear, that the oldest foundations of Etna were laid subsequently to the period when the Mediterranean became inhabited by the living species of testacea and zoophytes, yet we may be reconciled to such conclusions, when we find incontestable proofs of still greater revolutions beneath the surface within the same modern period.

Probable structure of the recent subterranean rocks of fusion.—Let us now inquire what form these unerupted newer Pliocene lavas of Sicily have assumed? For reasons already explained, we may infer that they cannot have been converted

into tuffs and peperinos, nor can we imagine that, under enormous pressure, they could have become porous, since we observe, that the lava which has cooled down under a moderate degree of pressure, in the dikes of Etna and Vesuvius, has a compact and porphyritic texture, and is very rarely porous or cellular. No signs of volcanic sand, scoriæ, breccia, or conglomerate are to be looked for, nor any of stratification, for all these imply formation in the atmosphere, or by the agency of water. The only proofs that we can expect to find of the *successive* origin of different parts of the fused mass, will be confined to the occasional passage of veins through portions previously consolidated. This consolidation would take place with extreme slowness, when nearer the source of volcanic heat and under enormous pressure, so that we must anticipate a perfectly crystalline and compact texture in all these subterranean products.

Now geologists have discovered, as we before stated, great abundance of crystalline and unstratified rocks in various parts of the globe, and these masses are particularly laid open to our view in those mountainous districts where the crust of the earth has undergone the greatest derangement. These rocks vary considerably in composition, and have received many names, such as granite, syenite, porphyry, and others. That they must have been formed by igneous fusion, and at many distinct eras, is now admitted; and their highly crystalline texture is such as might result from cooling down slowly from an intensely-heated state. They answer, therefore, admirably to the conditions required by the above hypothesis, and we therefore deem it probable that similar rocks have originated in the nether regions below the island of Sicily, and have attained a thickness of from one thousand to three thousand feet, since the newer Pliocene strata were deposited.

It is, moreover, very probable, that these fused masses have come into contact with subaqueous deposits far below the surface, in which case they may, in the course of ages, have greatly

altered their structure, just as dikes of lava render more crystalline the stratified masses which they traverse, and obliterate all traces of their organic remains.

Suppose some of these changes to have been superinduced upon subaqueous deposits underlying the tertiary formations of Sicily, it is important to reflect that in that case no geological proofs would remain of the era when the alterations had taken place; and if, at some future period, the whole island should be uplifted, and these rocks of fusion, together with the altered strata, should be brought up to the surface, it would not be apparent that they had assumed their crystalline texture in the newer Pliocene period. For aught that would then appear, they might have acquired their peculiar mineral texture at epochs long anterior, and might be supposed to have been formed before the planet was inhabited by living beings; instead of having originated at an era long subsequent to the introduction of the *existing species.*

CHANGES OF THE SURFACE DURING AND SINCE THE EMERGENCE OF THE NEWER PLIOCENE STRATA.

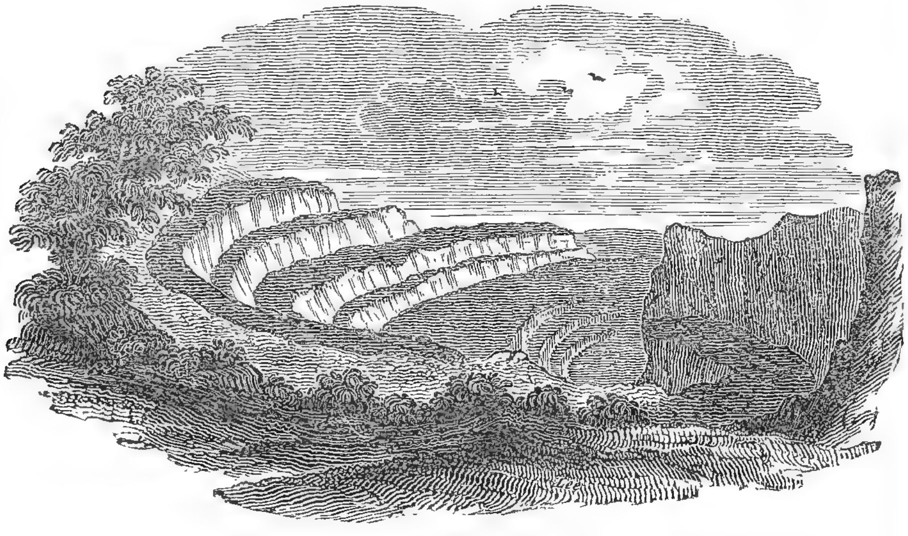
Valleys.—Geologists who are accustomed to attribute a great portion of the inequalities of the earth's surface to the excavating power of running water during a long series of ages, will probably look for the signs of remarkable freshness in the aspect of countries so recently elevated as the parts of Sicily already described. There is, however, nothing in the external configuration of that country which would strike the eye of the most practised observer, as peculiar and distinct in character from many other districts in Europe which are of much higher antiquity. The general outline of the hills and valleys would accord perfectly well with what may often be observed in regard to other regions of equal altitude above the level of the sea.

It is true that, towards the central parts of the island where the argillaceous deposits are of great thickness, as around Castrogiovanni, Caltanisetta, and Piazza, the torrents are observed

annually to deepen the ravines in which they flow, and the traveller occasionally finds that the narrow mule-path, instead of winding round the head of a ravine, terminates abruptly in a deep trench which has been hollowed out, during the preceding winter, through soft clay. But throughout a great part of Italy, where the marls and sands of the Subapennine hills are elevated to considerable heights, the same rapid degradation is often perceived.

In the limestone districts of the Val di Noto, the strata are for the most part nearly horizontal, and on each side of the valley form a succession of ledges or small terraces, instead of descending in a gradual slope towards the river-plain in the manner of the argillaceous formations. When there is a bend in the valley, the exact appearance of an amphitheatre with a range of marble seats is produced. A good example of this configuration occurs near the town of Melilli, in the Val di Noto, as seen in the annexed view (No. 22). In the south of

No. 22.



Valley called Gozzo degli Martiri, below Melilli.

the island, as near Spaccaforno, Scicli and Modica, precipitous rocks of white limestone, ascending to the height of five hundred feet, have been carved out into the same form.

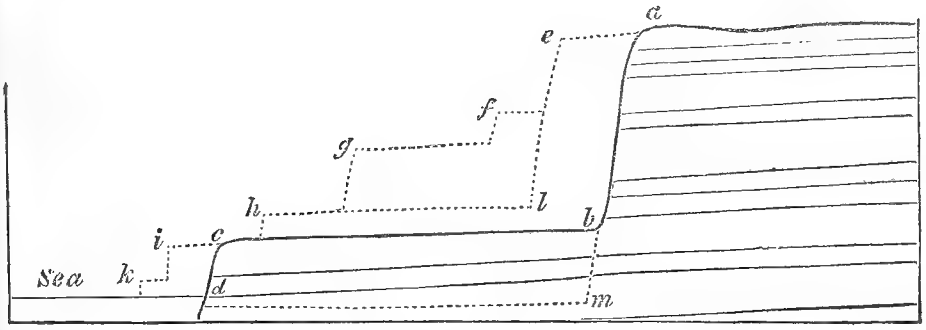
A careful examination of the mode of decomposition of the rock would be requisite, in order fully to explain this phenomenon. There is probably a tendency to a vertical fracture in

this as in many other limestones, which, when exposed to the action of frost, scale off in small fragments at right angles to the plane of stratification. It might have been expected that, in this case, a talus composed of a breccia of the limestone would be found on each ledge, so that the slope would become gradual, but perhaps the fragments instead of accumulating may decompose and be washed away by the heavy rains.

The line of some of the valleys near Lentini has evidently been determined mainly by the direction of the elevatory force, as there is an anticlinal dip in the strata on either side of the valley. The same is, probably, the case in regard to the great valley of the Anapo, which terminates at Syracuse.

Sea-cliffs—proofs of successive elevation.—No decisive evidence could be looked for in the form of the valleys to determine the question, whether the subterranean movements which upheaved the newer Pliocene strata in Sicily were very numerous or few in number. But we find the signs of two periods of elevation in a long range of inland cliff on the east side of the Val di Noto, both to the north of Syracuse, beyond Melilli, and to the south beyond the town of Noto. The great limestone formation before mentioned, terminates suddenly towards the sea in a lofty precipice, *a*, *b*, which varies in height from five

No. 23.



hundred to seven hundred feet, and may remind the English geologist of some of the most perpendicular escarpments of our chalk and oolite. Between the base of the precipice *a*, *b*, and the sea, is an inferior platform, *c*, *b*, consisting of similar white limestone. All the strata dip towards the sea,

but are usually inclined at a very slight angle; they are seen to extend uninterruptedly from the base of the escarpment into the platform, showing distinctly that the lofty cliff was not produced by a fault or vertical shift of the beds, but by the removal of a considerable mass of rock. Hence we must conclude that the sea, which is now undermining the cliffs of the Sicilian coast, reached at some former period the base of the precipice *a, b,* at which time the surface of the terrace *c, b,* must have constituted the bottom of the Mediterranean. Here, then, we have proofs of at least two elevations, but there may have been fifty others, for the encroachment of the sea tends to obliterate all signs of a *succession* of cliffs.

Suppose, for example, that a series of escarpments, *e, f, g, h,* once existed, and that during a long interval, free from subterranean movements, the sea had time to advance along the line *c, b,* all those ancient cliffs must then have been swept away one after the other, and reduced to the single precipice *a, b.* There may have been an antecedent period when the sea advanced along the line *h, l,* substituting the single cliff *e, l,* for the series *e, f, g.*

We may also imagine that the present cliffs may be the result of the union of several lines of smaller cliffs and terraces, which may once have been produced by a succession of elevatory movements. For example, the waves may have carried away the cliffs *k, i,* in advancing to *c, d.* In the same manner they may ultimately remove the mass *c, b, m, d,* and then the platform *c, b,* will disappear, and the precipice *a, m,* will be substituted for *a, b.*

We have stated, in the first volume, that the waves washed the base of the inland cliff near Puzzuoli, in the Bay of Baiæ, within the historical era, and that the retiring of the sea was caused, in the sixteenth century, by an upheaving of the land to an elevation of twenty feet above its original level. At that period, a terrace twenty feet high in some parts, was laid dry between the sea and the cliff, but the Mediterranean is hastening to resume its former position, when the terrace will be

destroyed, and every trace of the *successive* rise of the land will be obliterated.

We have been led into these observations, in order to show that the principal features in the physical geography of Sicily are by no means inconsistent with the hypothesis of the successive elevation of the country by the intermittent action of ordinary earthquakes *. On the other hand, we consider the magnitude of the valleys, and their correspondence in form with those of other parts of the globe, to lend countenance to the theory of the slow and gradual rise of subaqueous strata.

We have remarked in the first volume †, that the excavation of valleys must always proceed with the greatest rapidity when the levels of a country are undergoing alteration from time to time by earthquakes, and that it is principally when a country is rising or sinking by successive movements, that the power of aqueous causes, such as tides, currents, rivers, and land-floods, is exerted with the fullest energy.

In order to explain the present appearance of the surface, we must first go back to the time when the Sicilian formations were mere shoals at the bottom of the sea, in which the currents may have scooped out channels here and there. We must next suppose these shoals to have become small islands of which the cliffs were thrown down from time to time, as were those of Gian Greco, in Calabria, during the earthquake of 1783. The waves and currents would then continue their denuding action during the emergence of these islands, until at length, when the intervening channels were laid dry, and rivers began to flow, the deepening and widening of the val-

* Since writing the above I have read the excellent memoir of M. Boblaye, on the alterations produced by the sea on calcareous rocks on the shores of Greece. By examining the line of littoral caverns worn by the waves in cliffs composed of the harder limestones, together with the modes of decomposition of the rock, acted upon by the spray and sea air, as well as lithodomous perforations, and other markings, he has proved that there are four or five distinct ranges of ancient sea cliffs, one above the other, at various elevations in the Morea, which attest as many *successive* elevations of the country. Journal de Géologie, No. 10. Feb. 1831.

† Chap. xxiv.

leys by rivers and land-floods would proceed in the same manner as in modern times in Calabria, according to our former description *.

Before a tract could be upraised to the height of several thousand feet above the level of the sea, the joint operation of running water and subterranean movements must greatly modify the physical geography; but when the action of the volcanic forces has been suspended, when a period of tranquillity succeeds, and the levels of the land remain fixed and stationary, the erosive power of water must soon be reduced to a state of comparative equilibrium. For this reason, a country that has been raised at a very remote period to a considerable height above the level of the sea, may present nearly the same external configuration as one that has been more recently uplifted to the same height.

In other words, the time required for the raising of a mass of land to the height of several hundred yards must usually be so enormous (assuming as we do that the operation is effected by ordinary volcanic forces), that the aqueous and igneous agents will have time before the elevation is completed to modify the surface, and imprint thereon the ordinary forms of hill and valley, by which our continents are diversified. But after the cessation of earthquakes these causes of change will remain dormant, or nearly so. The greater part, therefore, of the earth's surface will at each period be at rest, simply retaining the features already imparted to it, while smaller tracts will assume, as they rise successively from the deep, a configuration perfectly analogous to that by which the more ancient lands were previously distinguished.

Migration of animals and plants.—The changes which, according to the views already explained, have been brought about in the earth's crust by the agency of volcanic heat, cannot fail to strike the imagination, when we consider how recent in the calendar of nature is the epoch to which we refer them. But if we turn our thoughts to the organic world, we shall feel,

* Chap. xxiv.

perhaps, no less surprise at the great vicissitude which it has undergone during the same period.

We have seen that a large portion of Sicily has been converted from sea to land since the Mediterranean was peopled with the living species of testacea and zoophytes. The newly emerged surface, therefore, must, during this modern zoological epoch, have been inhabited for the first time with the terrestrial plants and animals which now abound in Sicily. It is fair to infer, that the existing terrestrial species are, for the most part, of as high antiquity as the marine, and if this be the case, a large proportion of the plants and animals, now found in the tertiary districts in Sicily, must have inhabited the earth before the newer Pliocene strata were raised above the waters. The plants of the Flora of Sicily are common, almost without exception, to Italy or Africa, or some of the countries surrounding the Mediterranean *, so that we may suppose the greater part of them to have migrated from pre-existing lands, just as the plants and animals of the Phlegræan fields have colonized Monte Nuovo, since that mountain was thrown up in the sixteenth century.

We are brought, therefore, to admit the curious result, that the flora and fauna of the Val di Noto, and some other mountainous regions of Sicily, are of higher antiquity than the country itself, having not only flourished before the lands were raised from the deep, but even before they were deposited beneath the waters. Such conclusions throw a new light on the adaptation of the attributes and migratory habits of animals and plants, to the changes which are unceasingly in progress in the inanimate world. It is clear that the duration of species is so great, that they are destined to outlive many important revolutions in the physical geography of the earth, and hence those innumerable contrivances for enabling the subjects of the animal and vegetable creation to extend their range, the inhabitants

* Professor Viviani of Genoa informed me, that, considering the great extent of Sicily, it was remarkable that its flora produced scarcely any, *if any peculiar indigenous* species, whereas there are several in Corsica, and some other Mediterranean islands.

of the land being often carried across the ocean, and the aquatic tribes over great continental spaces *. It is obviously expedient that the terrestrial and fluviatile species should not only be fitted for the rivers, valleys, plains, and mountains which exist at the era of their creation, but for others that are destined to be formed before the species shall become extinct; and, in like manner, the marine species are not only made for the deep or shallow regions of the ocean at the time when they are called into being, but for tracts that may be submerged or variously altered in depth during the time that is allotted for their continuance on the globe.

Recapitulation.—We may now briefly recapitulate some of the most striking results which we have deduced from our investigation of a single district where the newer Pliocene strata are largely developed.

In the first place, we have seen that a stratified mass of solid limestone, attaining sometimes a thickness of eight hundred feet and upwards, has been gradually deposited at the bottom of the sea, the imbedded fossil shells and corallines being almost all of recent species. Yet these fossils are frequently in the state of mere casts, so that in appearance they correspond very closely to organic remains found in limestones of very ancient date.

2dly. In some localities the limestone above-mentioned alternates with volcanic rocks such as have been formed by submarine eruptions, recurring again and again at distant intervals of time.

3dly. Argillaceous and sandy deposits have also been produced during the same period, and their accumulation has also been accompanied by submarine eruptions. Masses of mixed sedimentary and igneous origin, at least two thousand feet in thickness, can thus be shown to have accumulated since the sea was peopled with the greater number of the aquatic species now living.

4thly. These masses of submarine origin have, since their formation, been raised to the height of two thousand or three

* See vol. ii., chapters v., vi., and vii.

thousand feet above the level of the sea, and this elevation implies an extraordinary modification in the state of the earth's crust at some unknown depth beneath the tract so upheaved.

5thly. The most probable hypothesis in regard to the nature of this change, is the successive generation and forcible intrusion into the inferior parts of the earth's crust of lava which, after cooling down, may have assumed the form of crystalline unstratified rock, such as is frequently exhibited in those mountainous parts of the globe where the greatest alterations of level have taken place.

6thly. Great inequalities must have been caused on the surface of the new-raised lands during the emergence of the newer Pliocene strata, by the action of tides, currents, and rivers, combined with the disturbing and dislocating force of the elevatory movements.

7thly. There are no features in the forms of the valleys and sea-cliffs thus recently produced, which indicate the sudden rise of the strata to the whole or the greater part of their present altitude, while there are some proofs of distinct elevations at successive periods.

8thly. We may infer that the species of terrestrial and fluviatile animals and plants which now inhabit extensive districts, formed during the newer Pliocene era, were in existence not only before the new strata were raised, but before their materials were brought together at the bottom of the sea.

CHAPTER X.

Tertiary formations of Campania—Comparison of the recorded changes in this region with those commemorated by geological monuments—Differences in the composition of Somma and Vesuvius—Dikes of Somma, their origin—Cause of the parallelism of their opposite sides—Why coarser grained in the centre—Minor cones of the Phlegræan Fields—Age of the volcanic and associated rocks of Campania—Organic remains—External configuration of the country, how produced—No signs of diluvial waves—Marine Newer Pliocene strata visible only in countries of earthquakes—Illustrations from Chili—Peru—Parallel roads of Coquimbo—West-Indian archipelago—Honduras—East-Indian archipelago—Red Sea.

TERTIARY FORMATIONS OF CAMPANIA.

Comparison of recorded changes with those commemorated by geological monuments.—In the first volume we traced the various changes which the volcanic region of Naples is known to have undergone during the last 2000 years, and, imperfect as are our historical records, the aggregate effect of igneous and aqueous agency, during that period, was shown to be far from insignificant. The rise of the modern cone of Vesuvius, since the year 79, was the most memorable event during those twenty centuries; but in addition to this remarkable phenomenon, we enumerated the production of several new minor cones in Ischia, and of the Monte Nuovo, in the year 1538. We described the flowing of lava-currents upon the land and along the bottom of the sea, the showering down of volcanic sand, pumice, and scoriæ, in such abundance that whole cities were buried,—the filling up or shoaling of certain tracts of the sea, and the transportation of tufaceous sediment by rivers and land-floods. We also explained the evidence in proof of a permanent alteration of the relative levels of the land and sea in several localities, and of the same tract having, near Puzzuoli, been alternately upheaved, and depressed, to the amount of more than 20 feet. In connexion with these convulsions,

we pointed out that, on the shores of the Bay of Baiæ, there are recent tufaceous strata filled with fabricated articles, mingled with marine shells. It was also shown that the sea has been making gradual advances upon the coast, not only sweeping away the soft tuffs of the Bay of Baiæ, but excavating precipitous cliffs, where the hard Ischian and Vesuvian lavas have flowed down into the deep.

These events, we shall be told, although interesting, are the results of operations on a very inferior scale to those indicated by geological monuments. When we examine this same region, it will be said, we find that the ancient cone of Vesuvius, called Somma, is larger than the modern cone, and is intersected by a greater number of dikes,—the hills of unknown antiquity, such as Astroni, the Solfatara, and Monte Barbaro, formed by separate eruptions, in different parts of the Phlegræan fields, far outnumber those of similar origin, which are recorded to have been thrown up within the historical era. In place of modern tuffs of slight thickness, and single flows of lava, we find, amongst the older formations, hills from 500 to more than 2000 feet in height, composed of an immense series of tufaceous strata, alternating with distinct lava-currents. We have evidence that in the lapse of past ages, districts, not merely a few miles square, were upraised to the height of 20 or 30 feet above their former level, but extensive and mountainous countries were uplifted to an elevation of more than 1000 feet, and at some points more than 2000 feet above the level of the sea.

These and similar objections are made by those who compare the modern effects of igneous and aqueous causes, not with a part but with the whole results of the same agency in antecedent ages. Thus viewed in the aggregate, the leading geological features of each district must always appear to be on a colossal scale, just as a large edifice of striking architectural beauty seems an effort of superhuman power, until we reflect on the innumerable minute parts of which it is composed. A mountain mass, so long as the imagination is occu-

pied in contemplating the gigantic whole, must appear the work of extraordinary causes, but when the separate portions of which it is made up are carefully studied, they are seen to have been formed successively, and the dimensions of each part, considered singly, are soon recognized to be comparatively insignificant, and it appears no longer extravagant to liken them to the recorded effects of ordinary causes.

Difference in the composition of Somma and Vesuvius.

As no traditional accounts have been handed down to us of the eruptions of the ancient Vesuvius, from the times of the earliest Greek colonists, the volcano must have been dormant for many centuries, perhaps for thousands of years, previous to the great eruption in the reign of Titus. But we shall afterwards show that there are sufficient grounds for presuming this mountain, and the other igneous products of Campania, to have been produced during the Newer Pliocene period.

We stated in the first volume *, that the ancient and modern cones of Vesuvius were each a counterpart of the other in structure; we may now remark that the principal point of difference consists in the greater abundance in the older cone of fragments of stratified rocks ejected during eruptions. We may easily conceive that the first explosions would act with the greatest violence, rending and shattering whatever solid masses obstructed the escape of lava and the accompanying gases, so that great heaps of ejected pieces of sedimentary rock would naturally occur in the tufaceous breccias formed by the earliest eruptions. But when a passage had once been opened and an habitual vent established, the materials thrown out would consist of liquid lava, which would take the form of sand and scoriæ, or of angular fragments of such solid lavas as may have choked up the vent.

Among the angular fragments of solid rock which abound in the tufaceous breccias of Somma, none are more common than a saccharoid dolomite, supposed to have been derived

* Chap. xx.

from an ordinary limestone altered by heat and volcanic vapours.

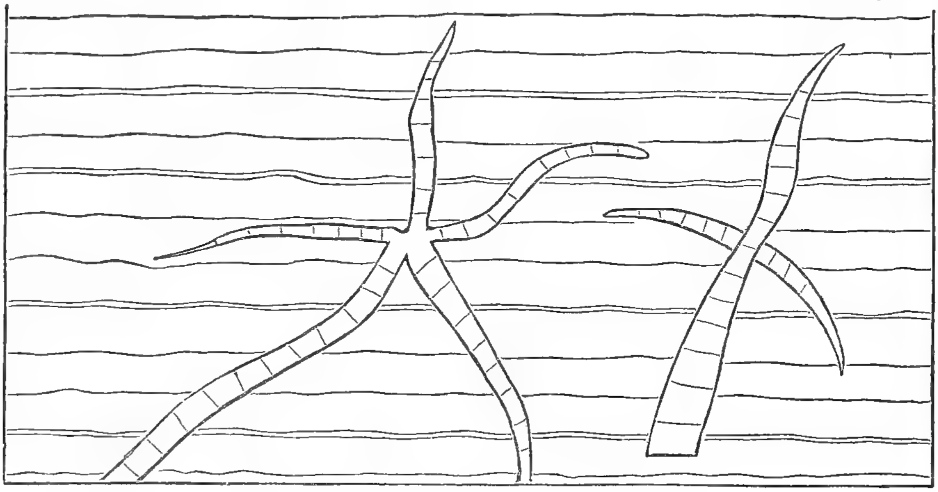
Carbonate of lime enters into the composition of so many of the simple minerals found in Somma, that M. Mitscherlich, with much probability, ascribes their great variety to the action of the volcanic heat on subjacent masses of limestone.

Dikes of Somma.—The dikes seen in the great escarpment which Somma presents towards the modern cone of Vesuvius are very numerous. They are for the most part vertical, and traverse at right angles the beds of lava, scoriæ, volcanic breccia, and sand, of which the ancient cone is composed. They project in relief several inches, or sometimes feet, from the face of the cliff, like the dikes of Etna already described (see woodcut No. 19), being, like them, extremely compact, and less destructible than the intersected tuffs and porous lavas. In height they vary from a few yards to 500 feet, and in breadth from one to twelve feet. Many of them cut all the inclined beds in the escarpment of Somma from top to bottom, others stop short before they ascend above half way, and a few terminate at both ends, either in a point or abruptly. In mineral composition they scarcely differ from the lavas of Somma, the rock consisting of a base of leucite and augite, through which large crystals of augite and some of leucite are scattered *. Examples are not rare of one dike cutting through another, and in one instance a shift or fault is seen at the point of intersection. We observed before †, when speaking of the dikes of the modern cone of Vesuvius, that they must have been produced by the filling up of open fissures by liquid lava. In some examples, however, the rents seem to have been filled laterally.

* Consult the valuable memoir of M. L. A. Necker, Mém. de la Soc. de Phys. et d'Hist. Nat. de Génève, tome ii. part i., Nov. 1822.

† Vol. i. chap. xx.

No. 25.



Dikes or veins at the Punto del Nasone on Somma.

The reader will remember our description of the manner in which the plain of Jerocarne, in Calabria, was fissured by the earthquake of 1783 *, so that the Academicians compared it to the cracks in a broken pane of glass. If we suppose the side walls of the ancient crater of Vesuvius to have been cracked in like manner, and the lava to have entered the rents and become consolidated, we can explain the singular form of the veins figured in the accompanying wood-cut †.

Parallelism of their opposite sides.—Nothing is more remarkable than the parallelism of the opposite sides of the dikes, which usually correspond with as much regularity as the two opposite faces of a wall of masonry. This character appears at first the more inexplicable, when we consider how jagged and uneven are the rents caused by earthquakes in masses of heterogeneous composition like those composing the cone of Somma; but M. Necker has offered an ingenious and, we think, satisfactory explanation of the phenomenon. He refers us to Sir W. Hamilton's account of an eruption of Vesuvius in the year 1779, who records the following facts. 'The lavas, when they either boiled over the crater, or broke out from the conical parts of the volcano, constantly formed channels as regular as if they had been cut by art, down the steep part of

* See vol. i. chap. xxiv., wood-cut No. 22.

† From a drawing of M. Necker, ibid.

the mountain, and, whilst in a state of perfect fusion, continued their course in those channels, which were sometimes full to the brim, and at other times more or less so according to the quantity of matter in motion.

'These channels, upon examination after an eruption, I have found to be in general from two to five or six feet wide, and seven or eight feet deep. They were often hid from the sight by a quantity of scoriæ that had formed a crust over them, and the lava, having been conveyed in a covered way for some yards, came out fresh again into an open channel. After an eruption I have walked in some of those subterraneous or covered galleries, which were exceedingly curious, the sides, top, and bottom, *being worn perfectly smooth and even* in most parts, by the violence of the currents of the red-hot lavas, which they had conveyed for many weeks successively.'

In another place, in the same memoir, he describes the liquid and red-hot matter as being received 'into a regular channel, raised upon a sort of wall of scoriæ and cinders, almost perpendicularly, of about the height of eight or ten feet, resembling much an ancient aqueduct *.'

Now, if the lava in these instances had not run out from the covered channel, in consequence of the declivity whereon it was placed—if, instead of the space being left empty, the lava had been retained within until it cooled and consolidated, it would then have constituted a small dike with parallel sides. But the walls of a vertical fissure through which lava has ascended in its way to a volcanic vent, must have been exposed to the same erosion as the four sides of the channels before adverted to. The prolonged and uniform friction of the heavy fluid as it flows upwards cannot fail to wear and smooth down the surfaces on which it rubs, and the intense heat must melt all such masses as project and obstruct the passage of the incandescent fluid.

We do not mean to assert that the sides of fissures caused by earthquakes are never smooth and parallel, but they are usually uneven, and are often seen to have been so where volcanic

* Phil. Trans., vol. lxx. 1780.

or *trap* dikes are as regular in shape as those of Somma. The solution, therefore, of this problem, in reference to the modern dikes, is most interesting, as being of very general application in geology.

Varieties in their texture.—Having explained the origin of the parallelism of the sides of a dike, we have next to consider the difference of its texture at the edges and in the middle. Towards the centre, observes M. Necker, the rock is coarser grained, the component elements being in a far more crystalline state, while at the edge the lava is sometimes vitreous and always finer grained. A thin parting band, approaching in its character to pitchstone, occasionally intervenes on the contact of the vertical dike and intersected beds. M. Necker mentions one of these at the place called Primo Monte, in the Atrio del Cavallo; I saw three or four others in different parts of the great escarpment. These phenomena are in perfect harmony with the results of the experiments of Sir James Hall and Mr. Gregory Watt, which have shown that a glassy texture is the effect of sudden cooling, and that, on the contrary, a crystalline grain is produced where fused minerals are allowed to consolidate slowly and tranquilly under high pressure.

It is evident that the central portion of the lava in a fissure would, during consolidation, part with its heat more slowly than the sides, although the contrast of circumstances would not be so great as when we compare the lava at the bottom and at the surface of a current flowing in the open air. In this case the uppermost part, where it has been in contact with the atmosphere, and where refrigeration has been most rapid, is always found to consist of scoriform, vitreous, and porous lava, while at a greater depth the mass assumes a more lithoidal structure, and then becomes more and more stony as we descend, until at length we are able to recognize with a magnifying glass the simple minerals of which the rock is composed. On penetrating still deeper, we can detect the constituent parts by the naked eye, and in the Vesuvian currents distinct crystals of augite and leucite become apparent.

The same phenomenon, observes M. Necker, may readily be exhibited on a smaller scale, if we detach a piece of liquid lava from a moving current. The fragment cools instantly, and we find the surface covered with a vitreous coat, while the interior, although extremely fine grained, has a more stony appearance.

It must, however, be observed, that although the lateral portions of the dikes are finer grained than the central, yet the vitreous parting layer before alluded to is extremely rare. This may, perhaps, be accounted for, as the above-mentioned author suggests, by the great heat which the walls of a fissure may acquire before the fluid mass begins to consolidate, in which case the lava, even at the sides, would cool very slowly. Some fissures, also, may be filled from above; and in this case the refrigeration at the sides would be more rapid than when the melted matter flowed upwards from the volcanic foci, in an intensely-heated state.

The rock composing the dikes of Somma is far more compact than that of ordinary lava, for the column of melted matter in a fissure greatly exceeds an ordinary stream of lava in weight, and the great pressure checks the expansion of those gases which give rise to vesicles in lava.

There is a tendency in almost all the Vesuvian dikes to divide into horizontal prisms, which are at right angles to the cooling surfaces *, a phenomenon in accordance with the formation of vertical columns in horizontal beds of lava.

Minor cones of the Phlegræan Fields.—In the volcanic district of Naples there are a great number of conical hills with craters on their summits, which have evidently been produced by one or more explosions, like that which threw up the Monte Nuovo in 1538. They are composed of trachytic tuff, which is loose and incoherent, both in the hills and, to a certain depth, in the plains around their base, but which is indurated below. It is suggested by Mr. Scrope, that this difference may be owing to the circumstance of the volcanic vents having burst out in a shallow sea, as was the case with Monte Nuovo, where there is a similar foundation of hard tuff, under a covering of

* See wood-cut No. 25.

loose lapilli. The subaqueous part may have become solid by an aggregative process like that which takes place in the setting of mortar, while the rest of the ejections, having accumulated on dry land when the cone was raised above the water, may have remained in a loose state *.

Age of the volcanic and associated rocks of Campania.—If we enquire into the evidence derivable from organic remains, respecting the age of the volcanic rocks of Campania, we find reason to conclude that such parts as do not belong to the recent, are referrible to the newer Pliocene period.

In the solid tuff quarried out of the hills immediately behind Naples, are found recent shells of the genera Ostrea, Cardium, Buccinum, and Patella, all referrible to species now living in the Mediterranean †. In Ischia I collected marine shells in beds of clay and tuff, not far from the summit of Epomeo, or San Nichola, about 2000 feet above the level of the sea, as also at another locality, about 100 feet below, on the southern declivity of the mountain, and others not far above the town of Moropano. At Casamicciol, and several places near the sea-shore, shells have long been observed in stratified tuff and clay. From these various points I obtained, during a short excursion in Ischia, 28 species of shells, all of which, with one exception, were identified by M. Deshayes with recent species ‡.

As the highest parts of Epomeo are composed of regularly-stratified greenish tuff, and some beds near the summit contain the fossils above-mentioned, it is clear that that mountain was not only raised to its present height above the level of the sea, but was also *formed* since the Mediterranean was inhabited by the existing species of testacea.

In the Ischian tuffs we find pumice, lapilli, angular fragments of trachytic lava, and other products of igneous ejections, interstratified with some deposits of clay, free from any intermixture of volcanic matter. These clays might have re-

* Geol. Trans., vol. ii. part iii. p. 351. Second Series.

† Scrope, ibid.

‡ See the list of these shells, Appendix II.

sulted from the decomposition of felspathic lava which abounds in Ischia, the materials having been transported by rivers and marine currents, and spread over the bottom of the sea where testacea were living. We may observe generally of these submarine tuffs, lavas, and clays, of Campania, that they strictly resemble those around the base of Etna, and in parts of the Val di Noto before described.

External configuration of the country how caused.—When once we have satisfied ourselves by inspection of the marine shells imbedded in tuffs at high elevations, that a mass of land like the island of Ischia has been raised from beneath the waters of the sea to its present height, we are prepared to find signs of the denuding action of the waves impressed upon the outward form of the island, especially if we conceive the upheaving force to have acted by successive movements. Let us suppose the low contiguous island of Procida to be raised by degrees until it attains the height of Ischia, we should in that case expect the steep cliffs which now face Misenum to be carried upwards and to become precipices near the summit of the central mountain. Such, perhaps, may have been the origin of those precipices which appear on the north and south sides of the ridge which forms the summit of Epomeo in Ischia. The northern escarpment is about 1000 feet in height, rising from the hollow called the Cavo delle Neve above the village of Panella. The abrupt manner in which the horizontal tuffs are there cut off, in the face of the cliff, is such as the action of the sea, working on soft materials, might easily have produced, undermining and removing a great portion of the mass. A heap of shingle which lies at the base of a steep declivity on the flanks of Epomeo, between the Cavo delle Neve and Panella, may once, perhaps, have been a sea-beach, for it certainly could not have been brought to the spot by any existing torrents.

There is no difficulty in conceiving that if a large tract of the bed of the sea near Ischia should now be gradually upheaved during the continuance of volcanic agency, this newly-raised land might present a counterpart to the Phlegræan fields before de-

scribed. Masses of alternating lava and tuff, the products of submarine eruptions, might on their emergence become hills and islands; the level intervening plains might afterwards appear, covered partly by the ashes drifted and deposited by water, and partly by those which would fall after the laying dry of the tract. The last features imparted to the physical geography would be derived from such eruptions in the open air as those of Monte Nuovo and the minor cones of Ischia.

No signs of diluvial waves.—Such a conversion of a large tract of sea into land might possibly take place while the surface of the contiguous country underwent but slight modification. No great wave was caused by the permanent rise of the coast near Puzzuoli in the year 1538, because the upheaving operation appears to have been effected by a long succession of minor shocks *. A series of such movements, therefore, might produce an island like Ischia without throwing a diluvial rush of waters upon low parts of the neighbouring continent. The advocates of paroxysmal elevations may, perhaps, contend that the rise of Ischia must have been anterior to the birth of all the cones of loose scoriæ scattered over the Phlegræan Fields, for, according to them, the sudden rise of marine strata causes inundations which devastate adjoining continents. But the absence of any signs of such floods in the volcanic region of Campania does not appear to us to warrant the conclusion, either that Ischia was raised previously to the production of the volcanic cones, or that it may not have been rising during the whole period of their formation.

We learn from the study of the mutations now in progress, that one part of the earth's surface may, for an indefinite period, be the scene of continued change, while another, in the immediate vicinity, remains stationary. We need go no farther than our own country to illustrate this principle; for, reasoning from what has taken place in the last ten centuries, we must anticipate that in the course of the next 4000 or 5000 years, a long strip of land, skirting the line of our eastern

* See vol. i. p. 457, first edition; p. 527, second edition.

coast, will be devoured by the ocean, while part of the interior, immediately adjacent, will remain at rest and entirely undisturbed. The analogy holds true in regions where the volcanic fires are at work, for part of the Philosopher's Tower on Etna has stood for the last 2000 years, at the height of more than 9000 feet above the sea, between the foot of the highest cone and the edge of the precipice which overhangs the Val del Bove, whilst large tracts of the surrounding district have been the scenes of tremendous convulsions. The great cone above has more than once been blown into the air, and again renewed; the earth has sunk down in the neighbouring Cisterna *; the cones of 1811 and 1819 have started up, on the ledge of rock below, pouring out of their craters two mighty streams of lava; the watery deluge of 1755 has rushed down from the steep desert region, into the Val del Bove, rolling along vast heaps of rocky fragments towards the sea; fissures, several miles in length, have opened on the flanks of Etna; cities and villages have been shattered by partial earthquakes, or buried under lava and ashes;—yet the tower has stood as if placed on the most perilous point in Europe, to commemorate the stability of one part of the earth's surface, while others in immediate proximity have been subject to most wonderful and terrific vicissitudes.

Marine Newer Pliocene strata only visible in countries of earthquakes.—In concluding what we have to say of the marine and volcanic formations of the newer Pliocene period, we may notice the highly interesting fact, that the marine strata of this era have hitherto been found at great elevations in those countries only where violent earthquakes have occurred during the historical ages. We do not deny that some *partial* deposits containing recent marine shells have been discovered at a considerable height in several maritime countries in Europe and elsewhere, far from the existing theatres of volcanic action; but stratified deposits of great extent and thickness, and replete with recent species, have only been observed to enter largely into the

* See above, p. 96.

structure of the interior, as in Sicily, Calabria, and the Morea, where subterranean movements are now violent. On the other hand, it is a still more striking fact, that there is no example of any extensive maritime district, now habitually agitated by great earthquakes, which has not, when carefully investigated, yielded traces of marine strata, either of the Recent or newer Pliocene eras, at considerable elevations.

Chili.—Conception Bay.—In illustration of the above remarks we may mention, that on the western coast of South America marine deposits occur, containing precisely the same shells as are now living in the Pacific. In Chili, for example, as we before stated *, micaceous sand, containing the fossil remains of such species as now inhabit the Bay of Conception, are found at the height of from 1000 to 1500 feet above the level of the ocean. It is impossible to say how much of this rise may have taken place during the *Recent* period. We have endeavoured to show that one earthquake raised this part of the Chilian coast, in 1750, to the height of at least 25 feet above its former level. If we could suppose a continued series of such shocks, one in every century, only 6000 years would be required to uplift the coast 1500 feet. But we have no data for inferring that so great a quantity of elevation has taken place in that space of time, and although we cannot assume that the micaceous sand may not belong to the Recent period, we think it more probable that it was deposited during the newer Pliocene period.

Peru.—We are informed by Mr. A. Cruckshanks, that in the valley of Lima, or Rimao, where the subterranean movements have been so violent in recent times, there are indications not only of a considerable rise of the land, but of that rise having resulted from *successive* movements. Distinct lines of ancient sea-cliffs have been observed at various heights, at the base of which the hard rocks of greenstone are hollowed out into precisely those forms which they now assume between high and low water mark on the shores of the Pacific. Immediately below these water-worn lines are ancient beaches strewed with

* Vol. i. chap. xxv.

rounded blocks. One of these cliffs appears in the hill behind Baños del Pujio, about 700 feet above the level of the sea, and 200 above the contiguous valley. Another occurs at Amancaes, at the height of perhaps 200 feet above the sea, and others at intermediate elevations.

Parallel roads of Coquimbo.—We can hardly doubt that the parallel roads of Coquimbo, in Chili, described by Captain Hall, owe their origin to similar causes. These roads, or shelves, occur in a valley six or seven miles wide, which descends from the Andes to the Pacific. Their general width is from 20 to 50 yards, but they are, at some places, half a mile broad. They are so disposed as to present exact counterparts of one another, at the same level, on opposite sides of the valley. There are three distinctly characterized sets, and a lower one which is indistinct when approached, but when viewed from a distance is evidently of the same character with the others. Each resembles a shingle beach, being formed entirely of loose materials, principally water-worn, rounded stones, from the size of a nut to that of a man's head. The stones are principally granite and gneiss, with masses of schistus, whinstone, and quartz mixed indiscriminately, and all bearing marks of having been worn by attrition under water *.

The theory proposed by Captain Hall to explain these appearances is the same as that which had been adopted to account for the analogous parallel roads of Glen Roy in Scotland †. The valley is supposed to have been a lake, the waters of which stood, originally, at the level of the highest road, until a flat beach was produced. A portion of the barrier was then broken down, which allowed the lake to discharge part of its waters into the sea, and, consequently, to fall to the second level; and so on successively till the whole embankment was washed away, and the valley left as we now see it.

As I did not feel satisfied with this explanation, I applied to

* Captain Hall's South America, vol. ii. p. 9.

† See Sir T. D. Lauder, Ed. Roy. Soc. Trans., vol. ix., and Dr. Macculloch, Geol. Trans., 1st Series, vol. iv. p. 314.

my friend Captain Hall for additional details, and he immediately sent me his original manuscript notes, requesting me to make free use of them. In them I find the following interesting passages, omitted in his printed account. 'The valley is completely open towards the sea; if the roads, therefore, are the beaches of an ancient lake, it is difficult to imagine a catastrophe sufficiently violent to carry away the barrier which should not at the same time obliterate all traces of the beaches. I find it difficult also to account for the water-worn character of all the stones, for they have the appearance of having travelled over a great distance, being well rounded and dressed. They are in immense quantity too, and much more than one could expect to find on the beach of any lake, and *seem more properly to belong to the ocean.*'

We entertained a strong suspicion, before reading these notes, that the beaches were formed by the waves of the Pacific, and not by the waters of a lake; in other words, that they bear testimony to the successive rise of the land, not to the repeated fall of the waters of a lake. We have before cited the proofs adduced by M. Boblaye, that in the Morea there are four or five ranges of ancient sea-cliffs, one above the other, at various elevations, where limestone precipices exhibit lithodomous perforations and lines of ancient littoral caverns *. If we discover lines of parallel upraised cliffs, we ought to find parallel lines of elevated beaches on those coasts where the rocks are of a nature to retain, for a length of time, the marks imprinted on their surface. We may expect such indications to be peculiarly manifest in countries where the subterranean force has been in activity within comparatively modern times, and it is there that the hypothesis of paroxysmal elevations, and the instantaneous rise of mountain-chains, should first have been put to the test, before it was hastily embraced by a certain school of geologists.

West Indian Archipelago.—According to the sketch given by Maclure of the geology of the Leeward Islands †, the

* See above, p. 113.

† Quart. Journ. of Sci., vol. v. p. 311.

western range consists in great part of formations of the most modern period. It will be remembered, that many parts of this region have been subject to violent earthquakes; that in St. Vincent's and Guadaloupe there are active volcanos, and in some of the other islands boiling springs and solfataras. In St. Eustatia, there is a marine deposit, estimated at 1500 feet in thickness, consisting of coral limestone alternating with beds of shells, of which the species are, according to Maclure, the same as those now found in the sea. These strata dip to the south-west at an angle of about 45°, and both rest upon, and are covered by, cinders, pumice, and volcanic substances. Part of the madreporic rock has been converted into silex and calcedony, and is, in some parts, associated with crystalline gypsum. Alternations of coralline formations with prismatic lava and different volcanic substances also occur in Dominica and St. Christopher's, and the American naturalist remarks, that as every lava-current which runs into the sea in this archipelago is liable to be covered with corals and shells, and these again with lava, we may suppose an indefinite repetition of such alternations to constitute the foundation of each isle.

We do not question the accuracy of the opinion, that the fossil shells and corals of these formations are of recent species, for there are specimens of limestone in the Museum of the Jardin du Roi at Paris, from the Antilles, in which the imbedded shells are all or nearly all identical with those now living. Part of this limestone is soft, but some of the specimens are very compact and crystalline, and contain only the casts of shells. Of 30 species examined by M. Deshayes from this rock 28 were decidedly recent.

Honduras.—Shells sent from some of the recent strata of Jamaica, and many from the nearest adjoining continent of the Honduras, may be seen in the British Museum, and are identified with species now living in the West Indian seas.

East Indian Archipelago.—We have seen that the Indian ocean is one of the principal theatres of volcanic disturbance. We expect, therefore, that future researches in this quarter of

the globe will bring to light some of the most striking examples of marine strata upraised to great heights during comparatively modern periods.

From the observations of Dr. Jack, it appears that in the island of Pulo Nias, off the west coast of Sumatra, masses of corals of recent species can be traced from the level of the sea far into the interior, where they form considerable hills. Large shells of the Chama gigas (*Tridacna*, Lamk.) are scattered over the face of the country, just as they occur on the present reefs. These fossils are in such a state of preservation as to be collected by the inhabitants for the purpose of being cut into rings for the arms and wrists *.

Madeira.—The island of Madeira is placed between the Azores and Canaries, in both of which groups there are active volcanos, and Madeira itself was violently shaken by earthquakes during the last century. It consists in great part of volcanic tuffs and porous lava, intersected in some places, as at the Brazen Head, by vertical dikes of compact lava †. Some of the marine fossil shells, procured by Mr. Bowdich from this island, are referrible to recent species.

These examples may suffice for the present, and lead us to anticipate with confidence, that in almost all countries where changes of level have taken place in our own times, the geologist will find monuments of a prolonged series of convulsions during the Recent and newer Pliocene periods. Exceptions may no doubt occur where a particular line of coast is sinking down, yet even here we may presume, from what we know of the irregular action of the subterranean forces, that some cases of partial elevation will have been caused by occasional oscillations of level, so that modern subaqueous formations will, here and there, have been brought up to view.

We shall conclude by enumerating a few exceptions to the rule above illustrated—instances of elevation where no great earthquakes have been recently experienced.

* Geol. Trans., Second Series, vol. i. part ii. p. 397.

† MS. of Captain B. Hall.

Grosœil, near Nice.—At a spot called Grosœil, near Nice, east of the Bay of Villefranche, in the peninsula of St. Hospice, a remarkable bed of fine sand occurs at an elevation of about 50 feet above the sea *. This sand rests on inclined secondary rocks, and is filled with the remains of marine species all identical with those now inhabiting the neighbouring sea. No less than 200 species of shells, and several crustacea and echini, have been obtained by M. Risso, in a high state of preservation, although mingled with broken shells. The winds have blown up large heaps of similar sand to considerable heights, upon ledges of the steep coast farther westward, but the position of the deposit at Grosœil cannot be referred to such agency, for among the shells may be seen the large Murex Triton, Linn., and a species of Cassis, weighing a pound and a half.

Uddevalla.—The ancient beaches of the Norwegian and Swedish coasts, described in the first volume †, in which the shells are of living species, present more marked exceptions as being farther removed from any line of recent convulsion. They afford evidence of a rise of 200 feet or more of parts of those coasts during the newer Pliocene, if not the Recent epoch.

West of England.—The proofs lately brought to light of analogous elevations on our western shores, in Caernarvonshire and Lancashire, during some modern tertiary period, were before pointed out ‡; but the data are as yet exceedingly incomplete.

Western Borders of the Red Sea.—Another exception may be alluded to, for which we are indebted to the researches of Mr. James Burton. On the western shores of the Arabian gulf, about half way between Suez and Kosire, in the 28th degree of North latitude, a formation of white limestone and calcareous sand is seen, reaching the height of 200 feet above the sea. It is replete with fossil shells, all of recent species, which are in a beautiful state of preservation, many of them retaining their colour. I have been favoured with a list of

* I examined this locality in company with Mr. Murchison in 1828.

† Chap. xiii. ‡ See description of the map, vol. ii.

these shells, which will be found in Appendix II.* The volcano of Gabel Tor, situate at the entrance of the Arabian gulf, is the nearest volcanic region known to us at present.

We should guard the reader against inferring, from the facts above detailed, that marine strata of the newer Pliocene period have been produced exclusively in countries of earthquakes. If we have drawn our illustrations exclusively from modern volcanic regions, it is simply for this reason, that these formations have been made visible to us in those districts only where the conversion of sea into land has taken place in times comparatively modern. Other continents have, during the newer Pliocene period, suffered degradation, and rivers and currents have deposited sediment in other seas, but the new strata remain concealed wherever no subsequent alterations of level have taken place.

We believe, however, that to a certain limited extent the growth of new subaqueous deposits has been greatest where igneous and aqueous causes have co-operated. It is there, as we have explained in former chapters, that the degradation of land is most rapid, and it is there only that materials ejected from below, by volcanic explosions, are added to the sediment transported by running water †.

* These fossils are now in the museum of Mr. Greenough, in London, and duplicates, presented by him, in the cabinets of the Geological Society.

† See vol. i. chap. xxiv.; and vol. ii. chap. xviii.

CHAPTER XI.

Newer Pliocene fresh-water formations—Valley of the Elsa—Travertins of Rome—Osseous breccias—Sicily—Caves near Palermo—Extinct animals in newer Pliocene breccias—Fossil bones of Marsupial animals in Australian caves—Formation of osseous breccias in the Morea—Newer Pliocene alluviums—Difference between alluviums and regular subaqueous strata—The former of various ages—Marine alluvium—Grooved surface of rocks—Erratic blocks of the Alps—Theory of deluges caused by paroxysmal elevations untenable—How ice may have contributed to transport large blocks from the Alps—European alluviums chiefly tertiary—Newer Pliocene in Sicily—Löss of the Valley of the Rhine—Its origin—Contains recent shells.

FRESH-WATER FORMATIONS.

In this chapter we shall treat of the fresh-water formations, and of the cave breccias and alluviums of the newer Pliocene period.

In regard to the first of these, they must have been formed, in greater or less quantity, in nearly all the existing lakes of the world, in those, at least, of which the basins were formed before the earth was tenanted by man. If the great lakes of North America originated before that era, the sedimentary strata deposited therein, in the ages immediately antecedent, would, according to the terms of our definition, belong to the newer Pliocene period.

Valley of the Elsa.—As an example of the strata of this age, which have been exposed to view in consequence of the drainage of a lake, we may mention those of the valley of the Elsa, in Tuscany, between Florence and Sienna, where we meet with fresh-water marls and travertins full of shells, belonging to species which now live in the lakes and rivers of Italy. Valleys several hundred feet deep have been excavated through the lacustrine beds, and the ancient town of Colle stands on a hill composed of them. The subjacent formation consists of marine Subapennine beds, in which more than half the shells are

of recent species. The fresh-water shells which I collected near Colle are in a very perfect state, and the colours of the Neritinæ are peculiarly brilliant. The following six species, all of which now inhabit Italy, were identified by M. Deshayes: Paludina impura, Neritina fluviatilis, Succinea amphibia, Limneus auricularis, L. pereger. and Planorbis carinatus.

Travertins of Rome.—Many of the travertins and calcareous tufas which cap the hills of Rome may also belong to the same period. The terrestrial shells inclosed in these masses are of the same species as those now abounding in the gardens of Rome, and the accompanying aquatic shells are such as are found in the streams and lakes of the Campagna. On Mount Aventine, the Vatican, and the Capitol, we find abundance of vegetable matter, principally reeds encrusted with calcareous tufa, and intermixed with volcanic sand and pumice. The tusk of a mammoth has been procured from this formation, filled in the interior with solid travertin, wherein sparkling crystals of augite are interspersed, so that the bone has all the appearance of having been extracted from a hard crystalline rock *.

These Roman tufas and travertins repose partly on marine tertiary strata, belonging, perhaps, to the older Pliocene era, and partly on volcanic tuff of a still later date. They must have been formed in small lakes and marshes, which existed before the excavation of the valleys which divide the seven hills of Rome, and they must originally have occupied the lowest hollows of the country, whereas now we find them placed upon the summit of hills about 200 feet above the alluvial plain of the Tiber. We know that this river has flowed nearly in its present channel ever since the building of Rome, and scarcely any changes in the geographical features of the country have taken place since that era.

When the marine tertiary strata of this district were formed, those of Monte Mario for example, the Mediterranean was already inhabited by a large proportion of the existing species

* This fossil was shown me by Signor Riccioli at Rome.

of testacea. At a subsequent period, volcanic eruptions occurred, and tuffs were superimposed. The marine formation then emerged from the deep, and supported lakes wherein the fresh-water groups above described slowly accumulated, at a time when the mammoth abounded in the country. The valley of the Tiber was afterwards excavated, and the adjoining hills assumed their present shape, and then a long interval may, perhaps, have elapsed before the first human settlers arrived. Thus we have evidence of a chain of events all regarded as extremely recent by the geologist, but which, nevertheless, may have preceded, for an immense series of ages, a very remote era in the history of nations.

OSSEOUS BRECCIAS.

Sicily.—The breccias recently found in several caves in Sicily belong evidently to the period under consideration. We have shown, in the sixth chapter, that the cavernous limestone of the Val di Noto is of very modern date, as it contains a great abundance of fossil shells of recent species. But if any breccias are found in the caverns of this rock they must be of still later origin.

We are informed by M. Hoffmann, that the bones of the mammoth, and of an extinct species of hippopotamus, have been discovered in the stalactite of caves near Sortino, of which the situation is represented in the annexed diagram at *b*. The

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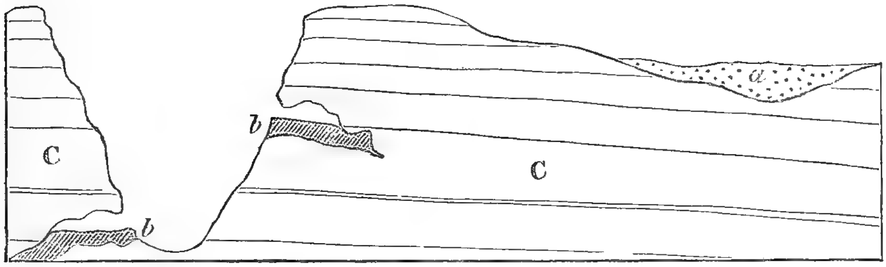


a, Alluvium, *b*, *b*, Deposits in caves, } containing remains of *extinct* quadrupeds.
C, Limestone containing remains of *recent* shells.

same author also describes a breccia, containing the bones of

an extinct rhinoceros and hippopotamus, in a cave in the neighbourhood of Syracuse, where the country is composed entirely of the Val di Noto limestone. Some of the fragments in the breccia are perforated by lithodomi, and the whole mass is covered by a deposit of marine clay filled with recent shells *. These phenomena may, we think, be explained by supposing such oscillations of level as are known to occur on maritime coasts where earthquakes prevail, such, in fact, as have been witnessed on the shores of the Bay of Baiæ within the last three centuries †. For it is evident that the temporary submergence of a cave filled with osseous breccia might afford time for the perforation of the rock by boring testacea, and for the deposition upon it of mud, sand, and shells.

The association in these and other localities of shells of living species with the remains of extinct mammalia is very distinct, and corroborates the inference adverted to in a former chapter, that the longevity of *species* in the mammalia is, upon the whole, inferior to that of the testacea. This circumstance we are by no means inclined to refer to the intervention of man, and his power of extirpating the larger quadrupeds, for the succession of mammiferous species appears to have been in like manner comparatively rapid throughout the older tertiary periods. Their more limited duration depends, in all probability, on physiological laws which render warm-blooded quadrupeds less capable, in general, of accommodating themselves to a great variety of circumstances, and, consequently, of surviving the vicissitudes to which the earth's surface is exposed in a great lapse of ages ‡.

Caves near Palermo.—The caves near Palermo exhibit appearances very analogous to those above described, and much curious information has been lately published respecting them. According to Hoffmann, the grotto of Mardolce is distant about two miles from Palermo, and is 20 feet high and 10

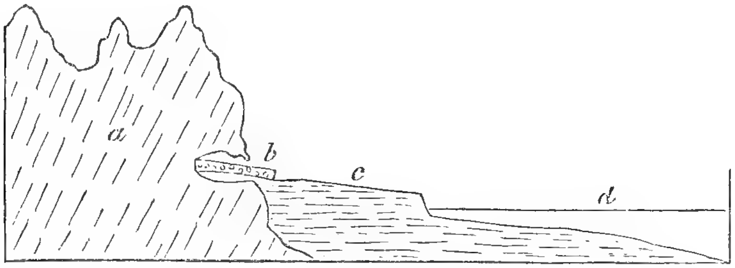
* Hoffmann, Archiv. für Mineralogie, p. 393. Berlin, 1831. Dr. Christie, Proceedings of Geol. Soc., No. xxiii. p. 333.

† Vol. i. chap. xxv.

‡ See above, p. 48, and vol. i. chap. vi.

wide. It occurs in a secondary limestone, in the Monte Grifone, at the base of a rocky precipice about 180 feet above the sea. From the foot of this precipice an inclined plane, consisting of horizontal tertiary strata, of the newer Pliocene period, extends to the sea, a distance of about a mile.

No. 27.



a, Monte Grifone. *c*, Plain of Palermo.
b, Cave of San Ciro. *d*, Bay of Palermo *.

The limestone escarpment was evidently once a sea-cliff, and the ancient beach still remains formed of pebbles of various rocks, many of which must have been brought from places far remote. Broken pieces of coral and shell, especially of oysters and pectens, are seen intermingled with the pebbles. Immediately above the level of this beach serpulæ are still found adhering to the face of the rock, and the limestone is perforated by lithodomi. Within the grotto also, at the same level, similar perforations occur, and so numerous are the holes, that the rock is compared by Hoffmann to a target pierced by musket balls. But in order to expose to view these marks of boring-shells in the interior of the cave, it was necessary first to remove a mass of breccia, which consisted of numerous fragments of rock and an immense quantity of bones imbedded in a dark brown calcareous marl. Many of the bones were rolled as if partially subjected to the action of the waves. Below this breccia, which is about 20 feet thick, was found a bed of sand filled with sea-shells of recent species, and underneath the

* This section is given by Dr. Christie, as of the Cave of San Ciro.—Ed. New Phil. Journ., No. xxiii. Its geographical position and other characters agree so precisely with that of Mardolce, described by M. Hoffmann, that it may be another name for the same cave, or one immediately adjoining.

sand again is the secondary limestone of Monte Grifone. The state of the surface of the limestone in the cave above the level of the marine sand is very different from that below it. *Above*, the rock is jagged and uneven, as is usual in the roofs and sides of limestone caverns; *below*, the surface is smooth and polished, as if by the attrition of the waves.

So enormous was the quantity of bones, that many ship-loads were exported in the years 1829 and 1830, in the hope of their retaining enough gelatine to serve for refining sugar, for which, however, they proved useless. The bones belong chiefly to the mammoth (*E. primigenius*), and with them are those of an hippopotamus, smaller than the species usually found fossil, and distinct from the recent. Several species of deer were also found with the above*. The remains of a bear, also, are said to have been discovered.

It is easy to explain in what manner the cavern of Mardolce was in part filled with sea-sand, and how the surface of the limestone became perforated by lithodomi; but in what manner, when the elevation of the rocks and the ancient beach had taken place, was the superimposed osseous breccia formed? The extraordinary number of the imbedded animal remains precludes, we think, at once the supposition of the whole having been heaped up together by a single catastrophe. Let us suppose that, when the caves were at a moderate elevation above the level of the sea, they were exposed, during a succession of earthquakes, to be inundated again and again by waves rolling in upon the land till they reached the base of an inland cliff, not far from the shore. Reiterated catastrophes may thus have occurred, like that of 1783 in Calabria, when a wave broke in upon the coast, and after sweeping away 1400 of the inhabitants and many cattle, threw in upon the land, on its return, the bodies of men and the carcasses of animals, mingled with sand and pebbles. Caves so flooded might be inhabited by some animals, and others might retreat into them during a period of alarm. We attach no importance, however, to these

* Cuvier, Disc. Prelim., p. 345, 6th Ed.

speculations, but merely throw them out as hints for those who may re-examine these caves and be desirous of collecting additional facts.

Two other caverns are described by Dr. Christie as occurring in Mount Beliemi, about four miles west of Palermo, at a higher elevation than that of Mardolce, being more than 300 feet above the level of the sea. In one of these localities the bones are only found in a talus at the outside of the cavern; in the other, they occur both within the cave and in the talus which slopes from it to the plain below. These caves appear to be situated much above the highest point attained by the tertiary deposits in this neighbourhood, nor is there the slightest appearance in the caves themselves of the sea having been there *.

The breccias in these caves may have originated in the manner before suggested, vol. ii. chap. xiii.

Australian Breccias.—In several parts of Australia, ossifferous breccias have lately been discovered in limestone caverns, and the remains of the fossil mammalia are found to be referrible to species now living in that country, mingled with some relics of extinct animals. Many of these have been examined by Major Mitchell in the Wellington Valley, about 210 miles west from Sidney, on the river Bell, one of the principal sources of the Macquarrie, and on the Macquarrie itself.

The caverns appear to correspond closely with those which contain similar osseous breccias in Europe; they often branch off in different directions through the rock, widening and contracting their dimensions, the roofs and floors being covered with stalactite. The bones are often broken, but do not appear water-worn. In some caves and fissures they lie imbedded in loose earth, but usually they are included in a breccia, having a red ochreous cement as hard as limestone, and like that of the Mediterranean caves.

The remains found most abundantly are those of the kangaroo. Amongst others, those of the Wombat, Dasyurus,

* Dr. T. Christie, on certain Newer Deposits in Sicily, &c.—Jameson, Ed. New Phil. Journ., No. xxiii. p. 1.

Kaola, and Phalangista, have been recognized. The greater part of them belong to existing, but several to extinct, species. One of the bones is of much greater size than the rest, and is supposed, by Mr. Clift, to belong to an hippopotamus *.

In a collection of these bones sent to Paris, Mr. Pentland thought he could recognize a species of Halmaturus of larger size than the largest living kangaroo †.

These facts are full of interest, for they prove that the peculiar type of organization which now characterizes the marsupial tribes has prevailed from a remote period in Australia, and that in that continent, as in Europe, North and South America, and India, many species of mammalia have become extinct. It also appears, although the evidence is less complete than we could have wished, that land quadrupeds, far exceeding in magnitude the wild species now inhabiting New Holland, have, at some former period, existed in that country.

Breccias now forming in the Morea.—Respecting the various ways in which fissures and caverns may become gradually filled up with osseous breccias, we may refer the reader to what we have said in a former volume ‡. It appears, however, from a recent communication of M. Boblaye, that the Morea is, of all the countries hitherto investigated, that which throws the greatest light on the mode in which the Mediterranean breccias may have originated.

In that peninsula a great many of the rivers and torrents terminate in land-locked hollows, where they are engulphed in chasms which traverse limestone. They sometimes reappear at great distances, but generally they discharge their waters below the level of the sea. 'Numerous bone caverns,' says M. Boblaye, 'may thus be filling up in our own times, and the gulphs (katavothrons) of the plain of Tripolitza have swallowed up of late years thousands of human bones, mingled

* Mr. Clift, Ed. New Phil. Journ., No. xx. p. 394.—Major Mitchell, Proceedings of Geol. Soc., 1831, p. 321.

† Journ. de Géologie, tome iii. p. 291. The bone of an *elephant* mentioned by Mr. Pentland was the same large bone alluded to by Mr. Clift.

‡ Vol. ii. chap. xiii.

with the same ochreous clay which envelops the osseous remains of higher antiquity *.'

NEWER PLIOCENE ALLUVIUMS.

Some writers have attempted to introduce into their classification of geological periods an *alluvial epoch*, as if the transportation of loose matter from one part of the surface of the land to another had been the work of one particular period.

In our opinion, they might have endeavoured, with equal propriety, to institute a volcanic period, or a period of marine or fresh-water deposits. We believe, on the contrary, that alluvial formations have originated in every age, but more particularly during those periods when land has been raised above its former level, or depressed below it. We defined alluvium to be such transported matter as has been thrown down, either by rivers, floods, or other causes, upon land liable to inundations, or which is not *permanently* submerged beneath the waters of lakes or seas †. As examples of the *other causes* adverted to in the above definition, we might instance a wave of the sea raised by an earthquake, or a water-spout, or a glacier.

We have said *permanently submerged* in order to distinguish between *alluviums* and regular subaqueous deposits. The latter are accumulated in lakes or great submarine receptacles, the former in the channels of rivers and currents, where the materials may be regarded as being still *in transitu*, or on their way to a place of rest. There may be cases where it is impossible to draw a line of demarcation between these two classes of formations, but these exceptions are rare, and the division is, upon the whole, convenient and natural, the circumstances being very different under which each group originates.

Marine alluvium.—The term 'marine alluvium' is, perhaps, admissible if confined to banks of shingle thrown up like the

* Journ. de Géologie, tome iii. No. x. p. 165.

† Vol. ii. chap. xiv.

Chesil bank, or to materials cast up by a wave of the sea upon the land, or those which a submarine current has left in its track. The kind last mentioned must necessarily, when the bed of the ocean has been laid dry, resemble terrestrial alluviums, with this difference, that if any fragments of organic bodies have escaped destruction they will belong to marine species.

During the gradual rise of a large area, first from beneath the waters, and then to a great height above them, several kinds of superficial gravel must be formed and transported from one place to another. When the first islets begin to appear, and the breakers are foaming upon the new-raised reefs, many rocky fragments are torn off and rolled along the bottom of the sea.

Let the reader recall to mind the action of the tides and currents off the coast of Shetland, described in the first volume*, where blocks of granite, gneiss, porphyry, and serpentine, of enormous dimensions, are continually detached from wasting cliffs during storms, and carried in a few hours to a distance of many hundred yards from the parent rocks. Suppose the floor of the ocean not far from the coast to be composed of those secondary strata of which several islands of this group consist. Such a tract, after being strewed over with detached blocks and pebbles of ancient rocks, might be converted into land, and the geologist might then, perhaps, search in vain for the islands whence the fragments were originally derived. For the islands may have wholly disappeared, having been gradually consumed by the waves of the ocean, or submerged by subterranean movements.

Let us farther suppose this new land to be uplifted during successive convulsions to the height of 1000 feet. The marine alluvium before alluded to would be carried upwards on the summits of the hills and on the surface of elevated platforms. It might still constitute the general covering of the country, being wanting only in such valleys and ravines as may have

* Chapter xv.

been caused by earthquakes or excavated by the power of running water during the rise of the land. The alluvium in those more modern valleys would consist partly of pebbles washed out of the older gravel before mentioned, but chiefly of fragments derived from the wreck of those rocks which were removed during the erosion of the valleys.

Many of the most widely distributed of the British alluviums may we think be referred to the action of the sea previous to the elevation of the land; and for this reason we never expect to be able to trace all the pebbles to their parent rocks. If it be objected that the high antiquity thus ascribed to many of our superficial deposits seems inconsistent with their actual state of preservation, we may observe, that they are often composed of indestructible materials, such as flint and quartz, and in many cases they have been protected for ages from the corroding action of the atmosphere by an envelope of loam or clay, from which they have been partially and slowly washed out by rain.

It must not, however, be understood that we refer the greater part of the alluviums scattered over our continents to the waves and currents of the sea, but merely some of those which have been justly regarded as most singular and anomalous, both in position and in the discordance of their contents with any known rocks in the adjacent countries.

Grooved surface of rocks.—We sometimes find the surface of large tracts hollowed out extensively in parallel grooves, such as have been described by Sir James Hall on the summits of the Corstorphine Hills, where I have myself examined them, in company with Dr. Buckland. These grooves may have been caused by the friction of blocks rolled along the floor of the ocean before the country emerged from the deep. The same appearances may be seen on a smaller scale, in the beds of many mountain-streams in Scotland, and I observed them strikingly displayed on Etna, in the defile called the Portella di Calanna, where a hard blue lava of modern date has been furrowed in this manner by the rolling of blocks down a steep declivity.

We have endeavoured, in a former volume, to point out the great power exerted by running water on the land in excavating valleys, at those periods when violent earthquakes derange, from time to time, the regular drainage of a country *. We also explained the manner in which temporary lakes are formed, and how the accumulated waters may suddenly escape, when the barriers are rent open by subsequent convulsions.

Erratic blocks.—Blocks of extraordinary magnitude have been observed at the foot of the Alps, and at a considerable height in some of the valleys of the Jura, exactly opposite the principal openings by which great rivers descend from the Alps. These fragments have been called 'erratic,' and many imaginary causes have been invented to account for their transportation. Some have talked of chasms opening in the ground immediately below, and of huge fragments having been cast out of them from the bowels of the earth. Others have referred to the deluge,—a convenient agent in which they find a simple solution of every difficult problem exhibited by alluvial phenomena. More recently, the instantaneous rise of mountain-chains has been introduced as a cause which may have given rise to diluvial waves, capable of devastating whole continents, and drifting huge blocks from one part of the earth's surface to another.

M. Elie de Beaumont has indulged in the speculation, that the sudden 'appearance of the Cordillera of the Andes' may have caused 'the historical deluge †!' Now, if we were sufficiently acquainted with the Andes to have grounds for assuming that they were not upheaved, like the Alps, at several successive periods;—if we could assume that they have started up at once, so as to attain their actual height in an instant of time;—if, in short, we could embrace the theory of 'paroxysmal elevations,' still we should consider the hypothesis of a connexion between the rise of the Andes and the historical

* Vol. i. chap. xxiv.

† L'Age relatif des Montagnes, sec. x.—Revue Française, No. xv., Mai, 1830, p. 55.

deluge, as most extravagant. It cannot be disputed that, if part of the unfathomable ocean were suddenly converted into a shoal, a great body of water would be displaced, and a diluvial wave might then inundate some previously-existing continent. A line of shoals, therefore, or reefs, consisting of shattered and dislocated rocks, and surrounded on all sides by a great depth of sea, ought first to have been pointed out by the paroxysmalist as one of the protruded masses which may have caused a recent deluge. The subsequent upthrow of these same reefs to an additional height of ten, fifteen, or twenty thousand feet, converting them suddenly into a mountain ridge like the Andes, would displace a great volume of atmospheric air, not of water, and if the velocity of the movement were sufficiently great, might occasion a tremendous hurricane.

If it be said that a convulsion sufficiently violent to raise the Andes would probably extend far beyond the immediate range of the mountain chain, we reply that, according to that theory, it was not the Andes, but some other unknown tract, part perhaps of the present bed of the Pacific, which occasioned the flood. And if we indulge in conjectures as to what may have happened in contiguous regions at the time when the Cordillera arose, we ask whether those regions may not have sunk down, so as to cause a subsidence instead of an uplifting of the oceanic waters?

But leaving the farther discussion of these speculative views, let us return to the origin of the larger erratic blocks of Alpine origin. It has been often suggested, that ice may have contributed its aid towards the transfer of these enormous blocks, and, as the transporting power of ice is now so conspicuously displayed in the Alps, the idea is entitled to the fullest consideration.

Those naturalists who have seen the glaciers of Savoy, and who have beheld the prodigious magnitude of some fragments conveyed by them from the higher regions of Mont Blanc to the valleys below, to a distance of many leagues, will be prepared to appreciate the effects which a series of earthquakes

might produce in this region, if the peaks or 'needles,' as they are called, of Mont Blanc were shaken as rudely as many parts of the Andes have been in our own times. The glaciers of Chamouni would immediately be covered under a prodigious load of rocky masses thrown down upon them. Let us, then, imagine one of the deep narrow gorges in the course of the Arve, between Chamouni and Cluse, to be stopped up by the sliding down of a hill-side (as the Rossberg fell in 1806 *), and a lake would fill the valley of Chamouni, and the lower parts of the glaciers would all be laid under water. The streams which flow out of arches, at the termination of each glacier, prove that at the bottom of those icy masses there are vaulted cavities through which the waters flow. Into these hollows the water of the lake would enter, and might thus float up the ice in detached icebergs, for the glaciers are much fissured, and the rents would be greatly increased during a period of earthquakes. Icebergs thus formed might, we conceive, resemble those seen by Captain Scoresby far from land in the Polar seas, which supported fragments of rock and soil, conjectured to be above fifty thousand tons in weight †. Let a subsequent convulsion, then, break suddenly the barrier of the lake, and the flood would instantly carry down the icebergs, together with their burden, to the low country at the base of the Alps.

We have stated in the first volume that blocks conveyed on floating icebergs must be deposited in different parts of the bottom of the ocean, in whatever latitudes those icebergs are dissolved ‡.

European alluviums in great part tertiary.—If those writers who speak of an 'alluvial epoch' intend merely to say that a great part of the European alluviums are *tertiary*, we fully coincide in that opinion, for the map of Europe, given in our second volume, will show that almost every part of the existing continent of Europe has emerged from beneath the waters

* See above, vol. ii. 1st Ed., p. 229; 2d Ed. p. 235.

† See above, vol. i. p. 299, 1st Ed.; p. 342, 2d Ed. ‡ Vol. i. ibid.

during some one or other of the tertiary periods; and it is probable, that even those districts which were land before the commencement of the tertiary epoch, may have shared in the subterranean convulsions by which the levels of adjoining countries have since been altered. During such subterranean movements new alluviums would be formed in great abundance, and those of more ancient date so modified as to retain scarcely any of their original distinguishing characters.

LOCALITIES OF NEWER PLIOCENE ALLUVIUMS.

Sicily.—Assuming, then, that almost all the European alluviums are tertiary, we have next to inquire which of them belong to the newer Pliocene period. It is clear that when a district, like the Val di Noto, is composed of rocks of this age, all the alluvium upon the surface must necessarily belong either to the newer Pliocene or to the Recent epoch. If, therefore, the elevation of the mountains of the Val di Noto was chiefly accomplished antecedently to the recent epoch, we must at once pronounce alluviums, in the position indicated at *a*, diagram No. 26 (p. 139), to belong to the newer Pliocene era. I am informed, that gravel so situated occurs at Grammichele in Sicily, containing the bones of the mammoth.

Loess of the Valley of the Rhine.—There is a remarkable alluvium filled with land-shells of recent species, which overspreads a great part of the valley of the Rhine, between Basle and Cologne, which, as it contains no remains of man or his works, we may refer to the newer Pliocene era. This deposit is provincially termed 'Loess,' or, in Alsace, 'Lehm,' and has been described by many geologists, whose observations we have lately had opportunities of verifying *.

According to M. Leonhard the loess consists chiefly of argillaceous matter combined with a sixth part of carbonate of lime and a sixth of quartzose and micaceous sand. It may be described as a pulverulent loam, of a dirty yellowish-grey colour,

* Among these we may mention MM. Leonhard, Bronn, Boué, Voltz, Steininger, Merian, Rozet, and Hibbert.

often containing calcareous sandy concretions or nodules, rarely exceeding the size of a man's head. Its entire thickness, in certain localities, amounts to several hundred feet; yet no signs of stratification appear in the mass, except here and there at the bottom, where there is a slight intermixture of materials derived from subjacent rocks. No marine remains are anywhere imbedded in it, but land-shells of *existing species* are extremely common, and the remains of the mammoth, horse, and some other quadrupeds, are said to have been found in it. The general absence of fresh-water shells is very remarkable. I collected a few specimens in the section near the Manheim gate of Heidelberg, and they are mentioned as having been found at a few other spots, by several of the writers above cited.

The loess sometimes rises to the height of 300 feet above the alluvial plain of the Rhine, and to the height of 600 feet above the sea; but it is confined to the valley of the Rhine and its tributary valleys, preserving everywhere the same mineral characters, except where the lowest portion is mixed up, as before-mentioned, with matter derived from the underlying rocks. The loess reposes on every rock, from the granite to the gravel of the plains of the Rhine, and must have been thrown down from some vast body of water, densely charged with sediment, after the country had assumed its present configuration. I am informed by M. Studer, that it does not extend into Switzerland, so that we may suppose the flood to have descended from near the borders of that country, perhaps from the neighbourhood of Basle, into the valley of the Rhine, where one of the first great obstacles to its passage would be the Kaiserstuhl, a small group of volcanic hills which stand almost in the middle of the plains of the Rhine, south of Strasburg, between the chains of the Black Forest and the Vosges. These hills are covered nearly to their summits with loess. But the narrow gorge of Bingen and Andernach would cause the greatest obstruction, even if we suppose that defile to have been open when the flood descended, which was probably the case,

since we find the loess lower down the valley, on the flanks of the Siebengebirge.

We have stated that stratification is almost entirely wanting, but the movement of the muddy waters appears in some places to have torn up the subjacent soil, and then to have thrown down again the foreign matter, thus mingled with the loess, in layers and strata. An alternation of gravel and loess has resulted from this cause in the lower part of the section before alluded to at Heidelberg.

I observed a similar blending of the loess, and the variegated sandstone and red marl underlying it at Zeuten and Odenau, in a valley on the right bank of the Rhine, at a short distance from the Bergstrasse, between Wiesloch and Bruchsal, a locality pointed out to me by Professor Bronn. Near Andernach there is a similar intermixture and alternation of the lower beds of loess, with volcanic ejections such as are strewed over that country, a phenomenon from which some observers have too hastily inferred that the volcanic eruptions and the deposition of the loess were contemporaneous.

The Rhine throughout a great part of its course between the lake of Constance to the falls of Schaffhausen traverses a tertiary deposit, called in Switzerland *molasse*, which consists in some places of stratified yellow loam. At Stein, near Œningen, this loam is 150 feet thick, and resembles exceedingly the löss before described, except in being regularly stratified. If we could suppose the waters of a great lake like that of Constance to have been suddenly let free by an earthquake, and in their descent into the valley of the Rhine to have intersected such strata, we might imagine the waters to have become densely charged with loam, with which they may have parted as soon as their velocity was diminished by spreading over a wider space.

The catastrophe which brought down the loess must, for a time, have desolated the country, but, in the end, it has enriched the soil, constituting the most fertile parts of Alsace

and Lorraine, which were previously composed of barren sand and gravel.

The perfect state of preservation of the land-shells in the loess may have arisen from their having been floated in the turbid water in which there were no hard particles to injure them by friction. The occurrence of fresh-water shells is so rare as by no means to warrant the theory adopted by some, that the löss was formed in a lake instead of having been thrown down from a transient flood of muddy water. A few individual shells of aquatic species, the inhabitants, perhaps, of rivers or small ponds, may easily have been washed away and intermingled with the rest during the inundation. The names of fifteen species of recent shells, which I collected from the löss, are given in Appendix II.*

* M. Bronn of Heidelberg possesses a more extensive collection.

CHAPTER XII.

Geological monuments of the *older* Pliocene period—Subapennine formations—Opinions of Brocchi—Different groups termed by him Subapennine are not all of the same age—Mineral composition of the Subapennine formations—Marls—Yellow sand and gravel—Subapennine beds how formed—Illustration derived from the Upper Val d'Arno—Organic remains of Subapennine hills—Older Pliocene strata at the base of the Maritime Alps—Genoa—Savona—Albenga—Nice—Conglomerate of Valley of Magnan—Its origin—Tertiary strata at the eastern extremity of the Pyrenees.

OLDER PLIOCENE FORMATIONS.

We must now carry back our retrospect one step farther, and treat of the monuments of the era immediately antecedent to that last considered. We defined in the fifth chapter *, the zoological characters by which the strata of the older Pliocene period may be distinguished, and we shall now proceed at once to describe some of the principal groups which answer to those characters.

Subapennine strata.—The Apennines, it is well known, are composed chiefly of secondary rocks, forming a chain which branches off from the Ligurian Alps and passes down the middle of the Italian peninsula. At the foot of these mountains, on the side both of the Adriatic and the Mediterranean, are found a series of tertiary strata, which form, for the most part, a line of low hills occupying the space between the older chain and the sea. Brocchi, the first Italian geologist who described this newer group in detail, gave it the name of the Subapennines, and he classed all the tertiary strata of Italy, from Piedmont to Calabria, as parts of the same system. Certain mineral characters, he observed, were common to the whole, for the strata consist generally of light brown or blue marl, covered by yellow calcareous sand and gravel. There are also,

* Above, p. 54.

he added, some species of fossil shells which are found in these deposits throughout the whole of Italy.

In a catalogue, published by Lamarck, of 500 species of fossil-shells of the Paris basin, a small number only were enumerated as identical with those of Italy, and only 20 as agreeing with living species. This result, said Brocchi, is wonderful, and very different from that derived from a comparison of the fossil-shells of Italy, *more than half of which* agree with species now living in the Mediterranean, or in other seas, chiefly of hotter climates *.

He also stated, that it appeared from the observations of Parkinson, that the clay of London, like that of the Subapennine hills, was covered by sand (alluding to the Crag), and that in that upper formation of sand in England the species of shells corresponded much more closely with those now living in the ocean than did the species of the subjacent clay. Hence he inferred that an interval of time had separated the origin of the two groups. But in Italy, he goes on to say, the shells found in the marl and superincumbent sand belong entirely to the same group, and must have been deposited under the same circumstances †.

Notwithstanding the correctness of these views, Brocchi conceived that the Italian tertiary strata, as a whole, might agree with those of the basins of Paris and London, and he endeavoured to explain the discordance of their fossil contents by remarking, that the testacea of the Mediterranean differ now from those living in the ocean ‡. In attempting thus to assimilate the age of these distinct groups, he was evidently influenced by his adherence to the anciently-received theory of the gradual fall of the level of the ocean, to which, and not to the successive rise of the land, he attributed the emergence of the tertiary strata, all of which he consequently imagined to have remained under water down to a comparatively recent period.

Brocchi was perfectly justified in affirming that there were

* Conch. Foss. Subap., tom. i. p. 148. † Ibid., p. 147. ‡ Ibid., p. 166.

some species of shells common to all the strata called by him Subapennine; but we have shown that this fact is not inconsistent with the conclusion, that the several deposits may have originated at different periods, for there are species of shells common to all the tertiary eras. He seems to have been aware, however, of the insufficiency of his data, for in giving a list of species universally distributed throughout Italy, he candidly admits his inability to determine whether the shells of Piedmont were all identical with those of Tuscany, and whether those of the northern and southern extremities of Italy corresponded *.

We have already satisfactory evidence that the Subapennine beds of Brocchi belonged, at least, to three periods. To the Miocene we can refer a portion of the strata of Piedmont, those of the hill of the Superga, for example; to the older Pliocene belong the greater part of the strata of northern Italy and of Tuscany, and perhaps those of Rome; to the newer Pliocene, the tufaceous formations of Naples, the calcareous strata of Otranto, and probably the greater part of the tertiary beds of Calabria.

That there is a considerable correspondence in the arrangement and mineral composition of these different Italian groups is undeniable; but not that close resemblance which should lead us to assume an exact identity of age, even had the fossil remains been less dissimilar.

Very erroneous notions have been entertained respecting the contrast between the lithological characters of the Italian strata and certain groups of higher antiquity. Dr. Macculloch has treated of the Italian tertiary beds under the general title of 'elevated submarine alluvia,' and the overlying yellow sand and gravel may, according to him, be wholly, or in part, a terrestrial alluvium †. Had he visited Italy, we are persuaded that he would never have considered the tertiary strata of London and Paris as belonging to formations of a different order from the Subapennine groups, or as being more regu-

* Conch. Foss. Subap., tom. i. p. 143. † Syst. of Geol., vol. i. chap. xv.

larly stratified. He seems to have been misled by Brocchi's description, who contrasts the more crystalline and solid texture of the older secondary rocks of the Apennines with the loose and incoherent nature of the Subapennine beds, which resemble, he says, the mud and sand now deposited by the sea.

We have endeavoured, in the last chapter, to restrict within definite limits the meaning of the term *alluvium;* but if the Subapennine beds are to be designated 'marine alluvia,' the same name might, with equal propriety, be applied not only to the argillaceous and sandy groups of the London and Hampshire basins, but to a very great portion of our secondary series where the marls, clays, and sands are as imperfectly consolidated as the tertiary strata of Italy in general.

They who have been inclined to associate the idea of the more stony texture of stratified deposits with a comparatively higher antiquity, should consider how dissimilar, in this respect, are the tertiary groups of London and Paris, although admitted to be of contemporaneous date, or they should visit Sicily and behold a soft brown marl, identical in mineral character with that of the Subapennine beds, underlying a mass of solid and regularly-stratified limestone, rivalling the chalk of England in thickness. This Sicilian marl is older than the superincumbent limestone, but newer than the Subapennine marl of the north of Italy; for in the latter the extinct shells rather predominate over the recent, in the former the recent predominate almost to the exclusion of the extinct.

We shall now consider more particularly the characters of those Subapennine beds which we refer to the older Pliocene period.

Subapennine marls.—The most important member of the Subapennine formation is a marl which varies in colour from greyish brown to blue. It is very aluminous, and usually contains much calcareous matter and scales of mica. It often exhibits no lines of division throughout a considerable thickness, but in other places it is thinly laminated. Near Parma, for example, I have counted thirty distinct laminæ in

the thickness of an inch. In some of the hills near that city the marl attains, according to Signor Guidotti, a thickness of nearly 2000 feet, and is charged throughout with shells, many of which are such as inhabit a deep sea. They often occur in layers in such a manner as to indicate their slow and gradual accumulation. They are not flattened but are filled with marl. Beds of lignite are sometimes interstratified, as at Medesano, four leagues from Parma; subordinate beds of gypsum also occur in many places, as at Vigolano and Bargone, in the territory of Parma, where they are interstratified with shelly marl and sand. At Lezignano, in the Monte Cerio, the sulphate of lime is found in lenticular crystals, in which unaltered shells are sometimes included. Signor Guidotti, who showed me specimens of this gypsum, remarked, that the sulphuric acid must have been fully saturated with lime when the shells were enveloped, so that it could not act upon the shell. According to Brocchi, the marl sometimes passes from a soft and pulverulent substance into a compact limestone *, but it is rarely found in this solid form. It is also occasionally interstratified with sandstone.

The marl constitutes very frequently the surface of the country, having no covering of sand. It is sometimes seen reposing immediately on the Apennine limestone; more rarely gravel intervenes, as in the hills of San Quirico †. Volcanic rocks are here and there superimposed, as at Radicofani, in Tuscany, where a hill composed of marl, with some few shells interspersed, is capped by basalt. Several of the volcanic tuffs in the same place are so interstratified with the marls as to show that the eruptions took place in the sea during the older Pliocene period. At Acquapendente, Viterbo, and other places, hills of the same formation are capped with trachytic lava, and with tuffs which appear evidently to have been subaqueous.

Yellow Sand.—The other member of the Subapennine group, the yellow sand and conglomerate, constitutes, in most

* Conch. Foss. Subap., tom. i. p. 82. † Ibid., p. 78.

of the places where I have seen it, a border formation near the junction of the tertiary and secondary rocks. In some cases, as near the town of Sienna, we see sand and calcareous gravel resting immediately on the Apennine limestone, without the intervention of any blue marl. Alternations are there seen of beds containing fluviatile shells, with others filled exclusively with marine species; and I observed oysters attached to many of the pebbles of limestone. This locality appears to have been a point where a river, flowing from the Apennines, entered the sea in which the tertiary strata were formed.

Between Florence and Poggibonsi, in Tuscany, there is a great range of conglomerate of the Subapennine beds, which is seen for eleven miles continuously from Casciano to the south of Barberino. The pebbles are chiefly of whitish limestone with some sandstone. On receding from the older Apennine rocks, the conglomerate passes into yellow sand and sandstone, with shells, the whole overlying blue marl. In such cases we may suppose the deltas of rivers and torrents to have gained upon the bed of a sea where blue marl had previously been deposited.

The upper arenaceous group above described sometimes passes into a calcareous sandstone, as at San Vignone. It contains lapidified shells more frequently than the marl, owing probably to the more free percolation of mineral waters, which often dissolve and carry away the original component elements of fossil bodies and substitute others in their place. In some cases the shells imbedded in this group are silicified, as at San Vitale, near Parma, from whence I saw two species, one freshwater and the other marine (Limnea palustris, and Cytherea concentrica, Lamk.), both *recent* and perfectly converted into flint.

On the other hand, the shells of Monte Mario, near Rome, which are probably referrible to the same formation, are changed into calcareous spar, the form being preserved notwithstanding the crystallization of the carbonate of lime.

Mode of formation of the Subapennine beds.—The tertiary strata above described have resulted from the waste of the secondary rocks which now form the Apennines, and which

had become dry land before the older Pliocene beds were deposited. In the territory of Placentia we have an opportunity of observing the kind of sediment which the rivers are now bringing down from the Apennines. The tertiary marl of that district being too calcareous to be used for bricks or pottery, a substitute is obtained, by conveying into tanks the turbid waters of the rivers Braganza, Parma, Taro and Enza. In the course of a year a deposit of brown clay, much resembling some of the Subapennine marl, is procured, several feet in thickness, divided into thin laminæ of different shades of colour.

In regard to the sand and gravel, we see yellow sand thrown down by the Tiber near Rome, and by the Arno, at Florence. The northern part of the Apennines consists of a grey micaceous sandstone with an argillaceous base, alternating with shale, from the degradation of which brown clay and sand would result. If a river flow through such strata, and some one of its tributaries drains the ordinary limestone of the Apennines, the clay will become marly by the intermixture of calcareous matter. The sand is frequently yellow from being stained by oxide of iron, but this colour is by no means constant.

The similarity in composition of the tertiary strata in the basins of the Po, Arno, and Tiber, is merely such as might be expected to arise from their having been all derived from the disintegration of the same continuous chain of secondary rocks. But it does not follow that the latter rocks were all upheaved and exposed to degradation at the same time. The correspondence of the tertiary groups consists in their being all alike composed of marl, clay, and sand; but we might say the same of the London and Hampshire basins, although the English and Italian groups, thus compared, belong nearly to the two opposite extremes of the tertiary series.

The similarity in mineral character of the lacustrine deposit of the Upper Val d'Arno, and the marine Subapennine hills of northern Italy, ought, we think, to serve as a caution

to the geologist, not to infer too hastily a contemporaneous origin from identity of mineral composition. The deposit of the Upper Val d'Arno occurs nearly at the bottom of a deep narrow valley, which is surrounded by precipitous rocks of secondary sandstone and shale (the macigno of the Italians and greywacke of the Germans). Hills of yellow sand, of considerable thickness, appear around the margin of the small basin, while, towards the central parts, where there has been considerable denudation, and where the Arno flows, blue clay is seen underlying the yellow sand. The shells are of freshwater origin, but we shall speak more particularly of them when we discuss the probable age of this formation in the sixteenth chapter. We desire, at present, to call the reader's attention to the fact, that we have here, in an isolated basin, such a formation as would result from the waste of the contiguous secondary rocks of the Apennines, fragments of which rocks are found in the sand and conglomerate. We should expect that if the freshwater beds were removed, and the barrier of the lake-basin closed up again, similar sediment would be again deposited, for the aqueous agents would operate in the same manner, at whatever period they might be in activity. Now, the only difference, in mineral composition, between the lacustrine deposit above alluded to, and the ordinary marine strata of the Subapennine beds, consists in the absence of calcareous matter from the clay, the torrents flowing into the lake having passed over no limestone rocks.

The lithological character of the Subapennine beds varies in different parts of the peninsula both in colour and degree of solidity. The presence, also, or absence of lignite and gypsum, and the association or non-association of volcanic rocks, are causes of great local discrepancy. The superposition of the sand and conglomerate to the marl, on the other hand, is a general point of agreement, although there are exceptions to the rule, as at San Quirico before mentioned. The cause of this arrangement may be, as we before hinted, that the arenaceous groups were first formed on the coast where rivers entered, and when

these pushed their deltas farther out, they threw down the sand upon part of the bed of the sea already occupied by finer and more transportable mud.

Organic Remains.—I have been informed, by experienced collectors of the Subapennine fossils, that they invariably procure the greatest number in those winters when the rains are most abundant, an annual crop, as it were, being washed out of the soil to replace those which the action of moisture, frost, and the rays of the sun, soon reduce to dust upon the surface.

The shells in general are soft when first taken from the marl, but they become hard when dried. The superficial enamel is often well preserved, and many shells retain their pearly lustre, and even part of their external colour, and the ligament which unites the valves. No shells are more usually perfect than the microscopic, which abound near Sienna, where more than a thousand full-grown individuals are sometimes poured out of the interior of a single univalve of moderate dimensions. In some large tracts of yellow sand it is impossible to detect a single fossil, while in other places they occur in profusion.

The Subapennine testacea are referrible to species and families of which the habits are extremely diversified, some living in deep, others in shallow water, some in rivers or at their mouths. I have seen a specimen of a *fresh-water* univalve (Limnea palustris), taken from the blue marl near Parma, full of small *marine* shells. It may have been floated down by the same causes which carried wood and leaves into the ancient sea.

Blocks of Apennine limestone are found in this formation drilled by lithodomous shells. The remains not only of testacea and corals, but of fishes and crabs, are met with, as also those of cetacea, and even of terrestrial quadrupeds.

A considerable list of mammiferous species has been given by Brocchi and some other writers; and, although several mistakes have been made, and the bones of cetacea have sometimes been confounded with those of land animals, it is still indubitable that the latter were carried down into the sea when the Subapennine sand and marl were accumulated. The same

causes which drifted skeletons into lakes, such as that of the upper Val d'Arno, may have carried down others into firths or bays of the sea. The femur of an elephant has been disinterred with oysters attached to it, showing that it remained for some time exposed after it was drifted into the sea.

Strata at the base of the Maritime Alps.—If we pass from the Italian peninsula, and, following the borders of the Mediterranean, examine the tertiary strata at the foot of the Maritime Alps, we find formations agreeing in zoological characters with the Subapennine beds, and presenting many points of analogy in their mineral composition. The Alps, it is well known, terminate abruptly in the sea, between Genoa and Nice, and the steep declivities of that bold coast are continuous below the waters, so that a depth of many hundred fathoms is often found within stone's-throw of the beach. Exceptions occur only where streams and torrents enter the sea, and at these points there is always a low level tract, intervening between the mouth of the stream and the precipitous escarpment of the mountains.

In travelling from France to Genoa, by the new coast-road, we are principally conveyed along a ledge excavated out of the side of a steep slope or precipice, in the same manner as on the roads which traverse the great interior passes of the Alps, such as the Simplon and Mont Cenis, the difference being that, in this case, the traveller has always the sea below him, instead of a river. But we are obliged occasionally to descend by a zig-zag course into those low plains before alluded to, which, when viewed from above, have the appearance of bays deserted by the sea. They are surrounded on three sides by rocky eminences, and the fourth is open to the sea.

These leading features in the physical geography of the country are intimately connected with its geological structure. The rocks composing the Alpine declivities consist partly of primary formations, but more generally of secondary, which have undergone immense disturbance; but when we examine the low tracts before-mentioned, we find the surface covered

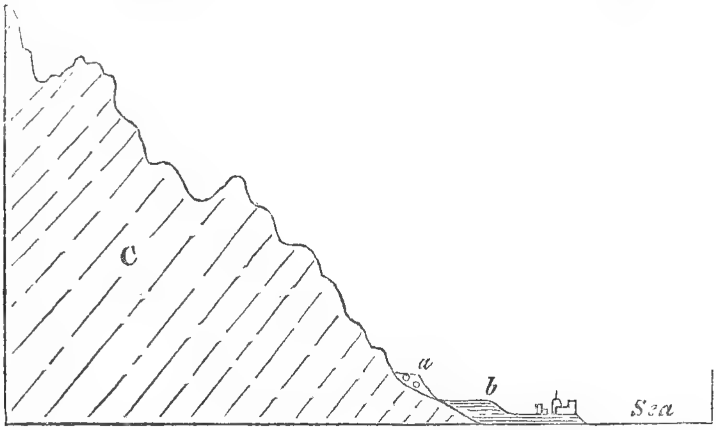
with great beds of gravel and sand, such as are now annually brought down by torrents and streams in the winter, and which are spread in such quantity over the wide and shifting river-channels as to render the roads for a season impassable. The first idea which naturally suggests itself, on viewing these plains, is to imagine them to be deltas or spaces converted into land by the accumulated sand and gravel brought down from the Alps by rivers. But, on closer inspection, we find that the apparent lowness of the plains, which at first glance might be supposed to be only just raised above the level of the sea, is a deception produced by contrast. The Alps rise suddenly to the height of several thousand feet with a bold and precipitous outline, while the country below is composed of horizontal strata, which have either a flat or gently-undulating surface. These strata consist of gravel, sand, and marl, filled with marine shells. They are considerably elevated, attaining sometimes the height of 200 feet, or even more, above the level of the sea; there must, therefore, have been a rise of the coast since they were deposited, and they are not mere deltas or spaces reclaimed from the sea by rivers. Why, then, are the strata found only at the points where rivers enter?

We must imagine that, after the coast had nearly acquired its present configuration, the streams which flowed down into the Mediterranean produced shoals opposite their mouths by the continual drifting in of gravel, sand, and mud. The Alps were afterwards raised to a sufficient height to cause these shoals to become land, while no perceptible alteration was produced on intervening parts of the coast, where the sea was of great depth near the shore.

The disturbing force appears to have acted very irregularly, and to have produced the least elevation towards the eastern extremity of the Maritime Alps, and a greater amount as we proceed westward. Thus we find the marine tertiary strata attaining the height of about 100 feet at Genoa, 200 and 300 feet farther westward, at Albenga, and 800 or 900 feet in the neighbourhood of Nice.

Genoa.—At Genoa the tertiary strata consist of blue marls like those of the northern Subapennines, and contain the same shells. On the immediate site of the town they rise to the height of only 20 feet above the sea, but they reach about 80 feet in some parts of the suburbs. At the base of a mountain not far from the suburbs there is an ancient

Monte d'Origina. No. 28.



Position of Tertiary strata at Genoa.

a, Ancient sea-beach. *b*, Blue marl with shells.
C, Inclined secondary strata of sandstone, shale, &c.

beach, strewed with rounded blocks of Alpine rocks, some of which are drilled by the *Modiola lithophaga*, Lamk., the whole cemented into a conglomerate*, which marks the ancient sea-beach at the height of 100 feet above the present sea.

Savona.—At Savona, proceeding westwards, we find deposits of blue marl like those of Genoa, and occupying a corresponding geological position at the base of the mountains near the sea. The shells, collected from these marls by Mr. Murchison and myself, in 1828, were examined by Signor Bonelli, of Turin, and found to agree with Subapennine fossils.

Albenga.—At Albenga these formations occupy a more extensive tract, forming the plains around that town and the low hills of the neighbourhood, which reach in some spots an elevation of 300 feet. The encircling mountains recalled to my mind those which bound the plain and bay of Palermo, and

* I have to acknowledge the assistance of Professor Viviani and Dr. Sasso who called my attention to these phenomena when I visited Genoa in Jan. 1829.

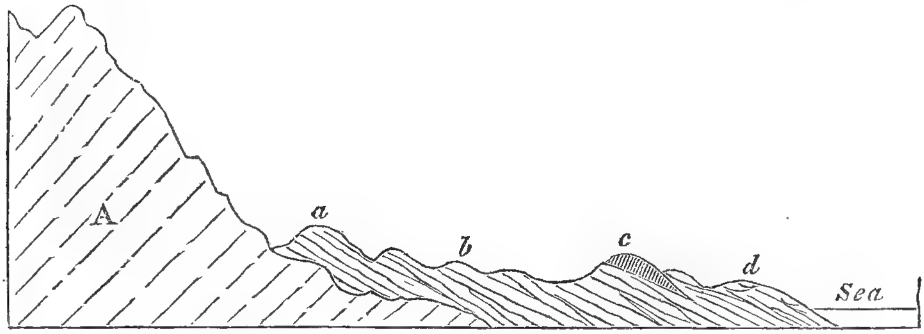
other bays of the Mediterranean, which are surrounded by bold rocky coasts.

The general resemblance of the Albenga strata to the Subapennine beds is very striking, the lowest division consisting of blue marl, which is covered by sand and yellow clay, and the highest by a mass of stratified shingle, sometimes consolidated into a conglomerate. Dr. Sasso has collected about 200 species of shells from these beds, and it appears, by his catalogue, that they agree, for the most part, with the northern Subapennine fossils, more than half of them belonging to recent species *.

Nice.—At Nice the tertiary strata are upraised to a much greater height, but they may still be said to lie at the base of the Alps which tower above them. Here, also, they consist principally of blue marl and yellow sand, which appear to have been deposited in submarine valleys previously existing in the inclined secondary strata. In one district, a few miles to the west of Nice, the tertiary beds are almost exclusively composed of conglomerate, from the point of their junction with the secondary strata to the sea.

The river Magnan flows in a deep valley which terminates at its upper extremity in a narrow ravine. Nearly vertical

Monte Calvo. No. 29.



Section from Monte Calvo to the sea by the valley of Magnan, near Nice.

A, Dolomite and sandstone. (Green-sand formation?)
a, b, d, Beds of gravel and sand.
c, Fine marl and sand of St. Madeleine.

* Giornale Ligustico, Genoa, 1827.

precipices are laid open on each side, varying from 200 to 600 feet in height, and composed of inclined beds of shingle, sometimes separated by layers of sand, and more rarely by blue micaceous marl. The pebbles in these stratified shingles agree in composition with those now brought down from the Alps by the Var and other rivers on this coast.

The dip of the strata is remarkably uniform, being always southwards, or towards the Mediterranean, at an angle of about 25°. In summer, when the bed of the river is dried up, the geologist has a good opportunity of examining a section of the strata, as the channel crosses for many miles the line of bearing of the beds, which may be traced to the base of Monte Calvo, a distance of about nine miles in a straight line from the Mediterranean *. It is usually impossible to determine the exact age of such accumulations of sand and gravel, in consequence of the total absence of organic remains. Their non-existence may depend chiefly on the disturbed state of the waters, where great beds of shingle are formed, which are known to prevent testacea and fishes from living in Alpine torrents, partly on the destruction of shells by the same friction which rounded the pebbles, and partly on the permeability of the matrix to water, which may carry away the elements of the decomposing fossil body, and substitute no others in their place which might retain a cast of their form.

But it fortunately happens, in this instance, that in some few seams of loamy marl, intervening between the pebble-beds, and near the middle of the section, shells have been preserved in a very perfect state of preservation, and these may furnish a zoological date to the whole mass. The principal of these interstratified masses of loam occurs near the church of St. Madeleine (at *c*, diagram No. 29), where the active researches of M. Risso have brought to light a great number of shells which agree perfectly with the species found in much greater abundance at a spot called La Trinità, and some other locali-

* I examined this section in company with Mr. Murchison in 1828.

ties nearer to Nice. From these fossils it clearly appears that the formation belongs to the older Pliocene era.

Such alternations of gravel and the usual thin layers of fine sediment may easily be explained, if we reflect that the rivers now flowing from the Maritime Alps are nearly dried up in summer, and have only strength to drift along fine mud to the sea; whereas, in winter, or on the melting of the snow, they roll along large quantities of pebbles. The thicker masses of loam, such as that of St. Madeleine, may have been produced during a longer interval, when the river shifted for a time the direction of its principal channel of discharge, so that nothing but fine mud was for a series of years conveyed to that point in the bed of the sea opposite the delta.

Uniform and continuous as the strata appear, on a general view, in the ravine of the Magnan, we discover, if we attempt to trace any one of them for some distance, that they thin out and are wedge-shaped. We believe that they were thrown down originally upon a steep slanting bank or talus, which advanced gradually from the base of Monte Calvo to the sea. The distance between these points is, as we have before mentioned, about nine miles, so that the accumulation of superimposed strata would be a great many miles in thickness, if they were placed horizontally upon one another. The strata nearest to Monte Calvo, which may be expressed by *a*, are certainly older than those at *b*, and the group *b* was formed before *c*. The aggregate thickness, in any one place, cannot be proved to amount to 1000 feet, although it may, perhaps, be much greater. But it may never exceed three or four thousand feet; whereas, if we did not suppose that the beds were originally deposited in an inclined position, we should be forced to imagine that a sea, many miles in depth, had been filled up by horizontal strata of pebbles thrown down one upon another.

At no great distance on this coast the Var is annually seen to sweep down into the sea a large quantity of gravel, which may be spread out by the waves and currents over a considerable space. The sea at the mouth of this river is now shallow,

but it may originally have been 3000 feet deep, as it is now close to the shore at Nice. Here, therefore, a formation resembling that of the Magnan above described may be in progress.

The time required for the accumulation of such a mass of conglomerate as we have just considered must be immense: on what ground such formations have been frequently referred to diluvial waves and to periods of great disturbance, we could never understand, for the causes now in diurnal action at the foot of the Maritime Alps and other analogous situations seem to us quite sufficient to explain their origin.

Tertiary strata at the eastern extremity of the Pyrenees.— We shall conclude this chapter with one more example derived from a region not far distant. On the borders of the Mediterranean at the eastern extremity of the Pyrenees, in the South of France, a considerable thickness of tertiary strata are seen in the valleys of the rivers Tech, Tet, and Gly. They bear much resemblance to those already described, consisting partly of a great thickness of conglomerate, and partly of clay and sand, with subordinate beds of lignite. They abut against the primary formation of the Pyrenees, which here consists of mica-schist. Between Ceret and Boulon these tertiary strata are seen inclined at an angle of between 20° and 30°. The shells which I procured from several localities were recognized by M. Deshayes as agreeing with Subapennine fossils.

Spain—Morea.—It appears from the recent observations of Colonel Silvertop, that marine strata of the older Pliocene period occur in patches at Malaga, and in Granada, in Spain. They have also been discovered by MM. Boblaye and Virlet in the Morea, and the names of many of the shells brought from thence are given in the Appendix No. I.

CHAPTER XIII.

Crag of Norfolk and Suffolk—Shown by its fossil contents to belong to the older Pliocene period—Heterogeneous in its composition—Superincumbent lacustrine deposits—Relative position of the crag—Forms of stratification—Strata composed of groups of oblique layers—Cause of this arrangement—Dislocations in the crag produced by subterranean movements—Protruded masses of chalk—Passage of marine crag into alluvium—Recent shells in a deposit at Sheppey, Ramsgate, and Brighton.

CRAG OF NORFOLK AND SUFFOLK.

THE older Pliocene strata, described in the last chapter, are all situated in countries bordering the Mediterranean, but we shall now consider a group in our own island, which belongs to the same era. We have already alluded to this deposit under the provincial name of crag *, and pointed out its superposition to the London clay, a tertiary formation of much higher antiquity †. The crag is chiefly developed in the eastern parts of Norfolk and Suffolk, from whence it extends into Essex.

Its relative age.—A collection of the shells of the 'crag' beds, which I formed in 1829, together with a much larger number sent me by my friend, Mr. Mantell of Lewes, were carefully examined by M. Deshayes, and compared to the tertiary species in his cabinet. This comparison gave the following result: out of 111 species, 66 were extinct or unknown, and 45 recent, the last, with one exception (*Voluta Lamberti*, Sow.), being now inhabitants of the German ocean. Such being the proportion of recent and extinct species, we may conclude, according to the rules before laid down ‡, that the crag belongs to the older Pliocene period.

Mineral composition.—So heterogeneous is this deposit in mineral character, that we can scarcely convey any correct notions of its appearance, without describing the beds separately in the different localities where they occur. In general, they

* Chap. ii. p. 19. † See above, Diagram No. 4, p. 21. ‡ Page 54.

consist of sand, gravel, and blue or brown marl—the shells imbedded in the sand and marl being, for the most part, broken and sometimes finely comminuted. In a few spots we find the deposit in the form of a soft stratified rock, composed almost entirely of corals, sponges, and echini *, an assemblage of species which probably lived in a tranquil sea of some depth. In other parts of our coast it consists of alternations of sand and shingle, destitute of organic remains, and more than 200 feet in thickness, as in the Suffolk cliffs, between Dunwich and Yarmouth. In others, we meet with an enormous mass, more than 300 feet in thickness, of sand, loam, and clay, containing bones of terrestrial quadrupeds and drift wood, sometimes stratified regularly, at others consisting of a confused heap of rubbish, in which fragments of the chalk and its flints are imbedded in a chalky marl.

In this aggregate are also found many fragments of older rocks, the septaria of the London clay, together with ammonites, vertebræ of ichthyosauri, and other fossils from parts of the oolitic series. It has been questioned whether all the above-mentioned beds can be considered as belonging to the same era. The subject may admit of doubt, but after examining, in 1829, the whole line of coast of Essex, Suffolk, and Norfolk, I found it impossible to draw any line of separation between the different groups. Each seemed in its turn to pass into another, and those masses which approach in character to alluvium, and contain the remains of terrestrial quadrupeds, are occasionally intermixed with the strata of the crag.

There are, however, lacustrine deposits overlying the crag, which probably belong to a distinct zoological period. These are found in small cavities, which must have existed on the surface of the crag after its elevation, and which formed small lakes or ponds wherein recent fresh-water testacea were included in loamy strata. (See wood-cut, No. 30, *c*.)

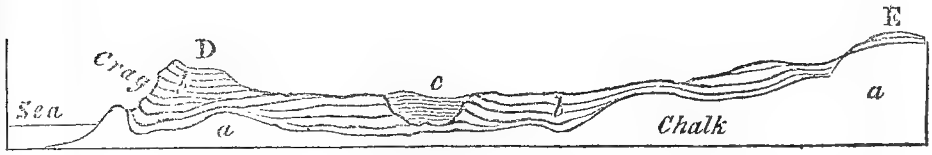
Relative position.—The crag is seen to rest on the chalk and on the London clay, but usually on the former. The strata

* R. Taylor, Geol. of East Norfolk.

are in great part horizontal, or slightly undulating; but at some points they are much disturbed, especially where several masses of chalk appear to have been protruded from below.

The annexed section may give a general idea of the manner in which the crag may be supposed to rest on the chalk as we pass from the Norfolk cliffs, at Trimmingham, into the interior, where the country rises gradually.

No. 30.



a, Chalk. *b*, Crag. *c*, Lacustrine deposit.
D, Trimmingham beacon. E, Interior and higher parts of Norfolk*.

The outline of the surface of the subjacent chalk, in this section, is imaginary, but is such as might explain the relations of those protruded masses, three of which appear in the cliffs near Trimmingham, and which some geologists have too hastily assumed to be unconnected with the great mass of chalk below. We shall treat of these presently, when we describe the disturbances which the crag appears to have suffered since its original deposition.

In the interior, at E, there is a thick covering of sand and gravel upon the chalk, having the characters of an alluvium, partly, perhaps, marine, and partly terrestrial, and which seems to pass gradually in this district into the regular marine strata of the crag.

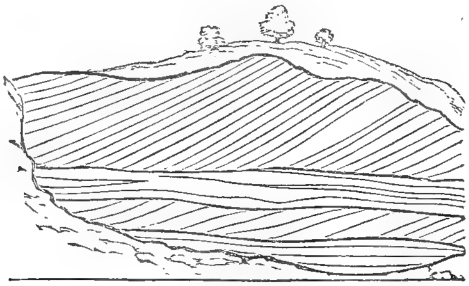
Forms of stratification.—In almost every formation the individual strata are rarely persistent for a great distance, the superior and inferior planes being seldom precisely parallel to each other; and if the materials are very coarse, the beds often thin out if we trace them for a few hundred yards. There are also many cases where all the layers are oblique to the general

* This section is compiled principally from one by Mr. Murchison, the others in this chapter are from drawings by the Author.

direction of the strata, and the crag affords most interesting illustrations of this phenomenon.

In the sea-cliff near Walton, in Suffolk, opposite the Martello Tower, called R, the section represented in the annexed diagram is seen. The vertical height is about 20 feet, and

No. 31.

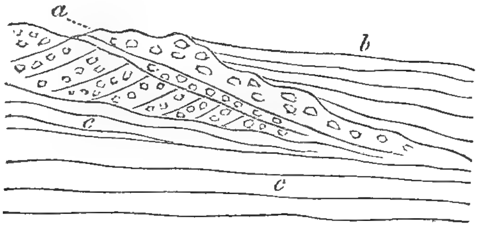


Section of shelly crag near Walton, Suffolk.

the beds consist alternately of sets of inclined and horizontal layers of sand and comminuted shells. The sand is siliceous and of a ferruginous colour, but the layers are sometimes made up of small plates of bivalve shells, arranged with their flat sides parallel to the plane of each layer, like mica in micaceous sandstones.

The number of laminæ in the thickness of an inch, both in the siliceous and shelly sand, varies from seven to ten in number, so that it is impossible to express them all in the diagram. The height of the uppermost stratum is, in this instance, remarkable, as it extends to twelve feet. The inclination of the laminæ is about 30°; but in the cliffs of Bawdesey, to the eastward, they are sometimes inclined at an angle of 45°, and even more.

No. 32.



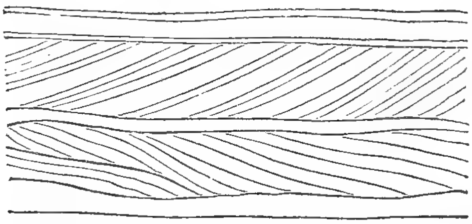
Section at the lighthouse near Happisborough. Height sixteen feet.

a, Pebbles of chalk flint, and of rolled pieces of white chalk.
b, Loam overlying *a*. *c*, *c*, Blue and brown clay.

This diagonal arrangement of the layers, sometimes called '*false* stratification,' is not confined to deposits of fine sand and comminuted shells, for we find beds of shingle disposed in the same manner as is seen in the annexed section (No. 32).

The direction of the dip of the inclined layers, throughout the Suffolk coast, is so uniformly to the south, that I only saw two or three instances of a contrary nature, where the inclination was northerly. One of the best examples of this variation is exhibited in a cliff between Mismer and Dunwich, wood-cut No. 33. In this case, there are about six layers in the thickness of an inch, and the part of the cliff represented is about six feet high.

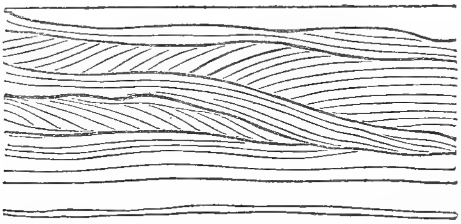
No. 33.



Section of part of Little Cat cliff, composed of quartzose sand, showing the inclination of the layers in opposite directions.

Another example may be seen near Walton, where the layers, which are of extreme tenuity, consist of ferruginous sand, brown loam, and comminuted shells. It is not uncommon to find in this manner sets of perfectly horizontal strata resting upon and covered by groups of wavy and transverse layers.

No. 34.

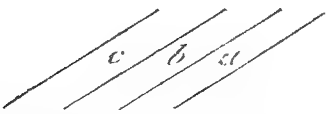


Lamination of shelly sand and loam, near the Signal-house, Walton. Vertical height four feet.

The appearances exhibited in the diagrams are not peculiar to the crag, and I have seen sand and pebble-beds of all ages, including the old red sandstone, greywacke, and clay-slate, exhibit the same arrangement.

When we inquire into the causes of such a disposition of the materials of each bed or group of layers, we may, in the first place, remark, that however numerous may be the successive layers *a*, *b*, *c*, the layer *a* must have been deposited before *b*, *b* before *c*, and so of the rest.

No. 35.



We must suppose that each thin seam was thrown down on a slope, and that it conformed itself to the side of the steep bank, just as we see the materials of a talus arrange themselves at the foot of a cliff when they have been cast down successively from above. If the transverse layers are cut off by a nearly horizontal line, as in many of the above sections, it may arise from the denuding action of a wave which has carried away the upper portion of a submarine bank and truncated the layers of which it was composed. But I do not conceive this hypothesis to be necessary; for if a bank have a steep side, it may grow by the successive apposition of thin strata thrown down upon its slanting side, and the removal of matter from the top may proceed simultaneously with its lateral extension. The same current may borrow from the top what it gives to the sides, a mode of formation which I had lately an opportunity of observing on the rippled surface of the hills of blown sand near Calais. The undulating ridges and intervening furrows on the dunes of blown sand resembled exactly in form those caused by the waves on a sea-beach, and were always at right angles to the direction of the wind which had produced them. Each ridge had one

No. 36.

side slightly inclined and the other steep, the lee side being always steep, as *b c*, *d e*, the windward side a gentle slope, as *a b*, *c d*. When a gust of wind blew with sufficient force to drive along a cloud of sand, all the ridges were seen to be in motion at once, each encroaching on the furrow before it, and, in the course of a few minutes, filling the place which the fur-

rows had occupied. Many grains of sand were drifted along the slopes *a b*, and *c d*, which, when they fell over the scarps *b c*, and *d e*, were under shelter from the wind, so that they remained stationary, resting, according to their shape and momentum, on different parts of the descent. In this manner each ridge was distinctly seen to move slowly on as often as the force of the wind augmented. We think that we shall not strain analogy too far if we suppose the same laws to govern the subaqueous and subaërial phenomena; and if so, we may imagine a submarine bank to be nothing more than one of the ridges of ripple on a larger scale, which may increase in the manner before suggested, by successive additions to the steep scarps.

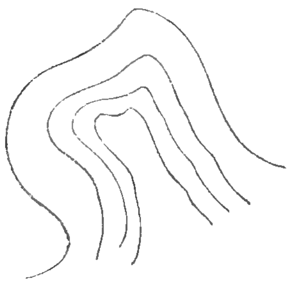
The set of tides and currents, in opposite directions, may account for sudden variations in the direction of the dip of the layers, as represented in the wood-cut, No. 33, while the general prevalence of a southerly inclination in the Crag of Suffolk may indicate that the matter was brought by a current from the north.

We may refer to a drawing given in the first volume*, to show the analogy of the arrangement of the submarine strata, just considered, to that exhibited by deposits formed in the channels of rivers where a considerable transportation of sediment is in progress.

Derangement in the Crag strata.—In the above examples we have explained the want of parallelism or horizontality in the subordinate layers of different strata, by reference to the mode of their original deposition; but there are signs of disturbance which can only be accounted for by subsequent movements. The same blue and brown clay, or loam, which is often perfectly horizontal, and as regularly bedded as any of our older formations, is, in other places, curved and even folded back upon itself, in the manner represented in the annexed diagrams.

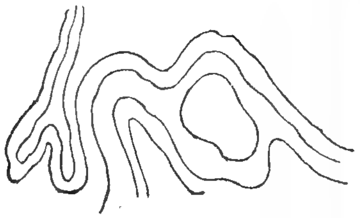
* Chap. xiv., Diag. No. 6.

No. 37.



Bent strata of loam in the cliffs between Cromer and Runton.

No. 38.

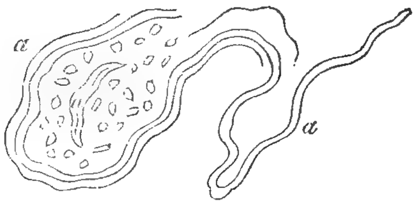


Folding of the strata between East and West Runton.

In the last of these cuts a central nucleus of sand is surrounded by argillaceous and sandy layers. This phenomenon is very frequent, and there are instances where the materials thus enveloped consist of broken flints mingled with pieces of chalk, forming a white mass encircled by dark laminated clay. The diameter of these included masses, as seen in sections laid open in the sea-cliffs, varies from five to fifteen feet.

East of Sherringham, a heap of partially-rounded flints, about five feet in diameter, is nearly enveloped by finely-laminated strata of sand and loam, and some of the loam is entangled in the midst of the flints.

No. 39.



Section in the Cliffs east of Sherringham.

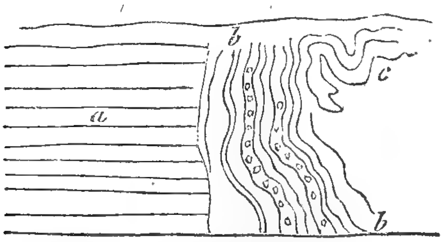
a, Sand and loam in thin layers.

In this and similar instances, we may imagine the yielding strata, *a*, to have subsided into a cavity, and the flints belonging to a superincumbent bed to have pressed down with their weight, so as to cause the strata to fold round them.

That some masses of stratified sand and loam have actually sunk down into cavities, or have fallen like landslips into ravines, seems indicated by other appearances. Thus, near Sherringham, the argillaceous beds, *a*, represented in the annexed diagram (No. 40), are cut off abruptly, and succeeded by the vertical and contorted series, *b*, *c*. The face of the cliff here

represented, is 24 feet in height. Some of the layers in *b*, *b*, are composed of pebbles, and these alternate with thin beds

No. 40.



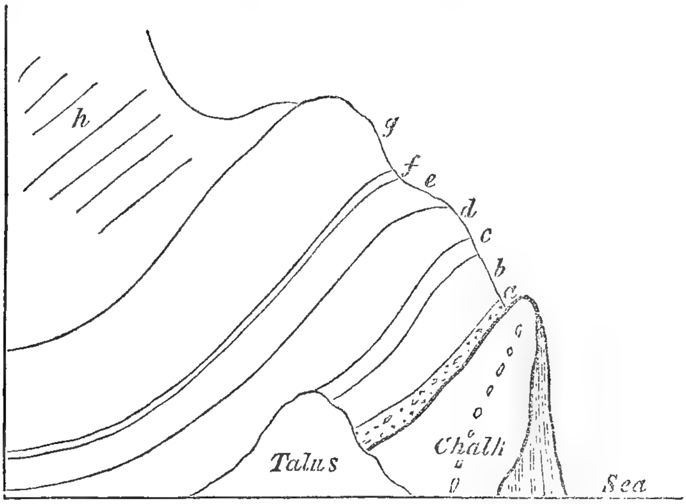
Section east of Sherringham, Norfolk.

a, Sand, loam, and blue clay. *b*, *b*, Sand and gravel. *c*, Twisted beds of loam.

of loose sand. The whole set must once have been horizontal, and must have moved in a mass, or the relative position of the several parts would not have been preserved. Similar appearances may, perhaps, be produced when chasms open during earthquakes and portions of yielding strata fall in from above and are engulphed.

Protruded masses of chalk.—But whatever opinion we may entertain on this point, we cannot doubt that subterranean

No. 41.



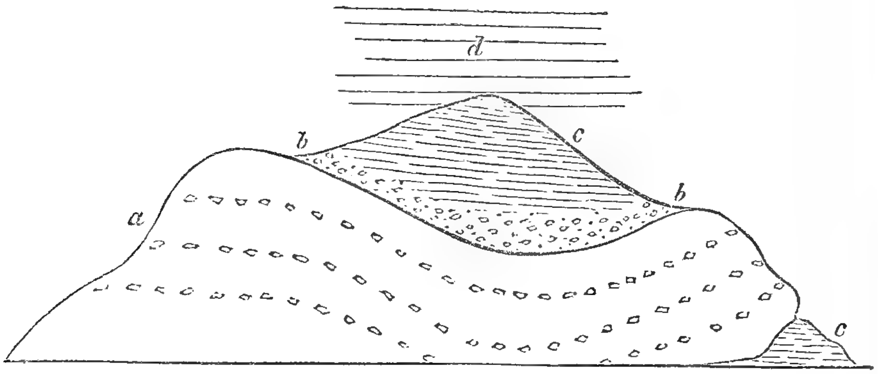
Side view of a promontory of chalk and crag, Trimmingham, Norfolk.

a, Gravel and ferruginous sand, rounded and angular pieces of chalk flint, with some quartz pebbles, 3 feet.
b, Laminated blue clay, 8 feet. *c*, Yellow sand, 1 foot 6 inches.
d, Dark blue clay with fragments of marine shells, 6 feet.
e, Yellow loam and flint gravel, 3 feet. *f*, Light blue clay, 1 foot.
g, Sand and loam, 12 feet.
h, Yellow and white sand, loam, and gravel, about 100 feet.

movements have given rise to some of the local derangements in this formation, particularly where masses of solid chalk pierce, as it were, the crag. Thus, between Mundesley and Trimmingham we see the appearances exhibited in the accompanying view (No. 41). The chalk, of which the strata are highly inclined, or vertical, projects in a promontory, because it offers more resistance to the action of the waves than the tertiary beds which, on both sides, constitute the whole of the cliff. The height of the soft crag strata immediately above the chalk is, in this place, about 130 feet. Those which are in contact (see the wood-cut) are inclined at an angle of 45°, and appear more disturbed than in other parts of the cliffs, as if they had been displaced by the movement by which the chalk was protruded.

Very similar appearances are exhibited by the northernmost of the three protuberances of chalk, of which a front view is given in the annexed diagram. It occupies a space of about 100 yards along the shore, and projects about 60 yards in advance of the general line of cliff. One of its edges, at *c*, rests upon

No. 42.



Northern protuberance of chalk, Trimmingham.

a. Chalk with flints.
b. Gravel, of broken and half-rounded flints.
c. Laminated blue clay.
d. Sand and yellow loam.

the blue clay beds of the crag, in such a manner as to imply that the mass had been undermined when the crag was deposited, unless we suppose, as some have done, that this chalk is a great detached mass enveloped by crag. For,

as one of the 'Needles', or insulated rocks of chalk, which projected 120 feet above high water-mark, at the western extremity of the Isle of Wight, fell into the sea in 1772 *, so a pinnacle of chalk may have been precipitated into the tertiary sea, at a point where some strata of the crag had previously accumulated. The beds of flint and chalk in the above diagram appear nearly horizontal, but they are in fact highly inclined inwards towards the cliff. The rapid waste of the Norfolk coast might soon enable us to understand the true position of this mass, if observations and drawings are made from time to time of the appearances which present themselves.

Perhaps it may be necessary to suppose, that subterranean movements were in progress during the deposition of the crag, and the extraordinary dislocations of the beds, in some places, which in others are perfectly regular and horizontal, may be most easily accounted for by introducing an alternate rise and depression of the bed of the sea, such as we know to be usually attendant on a series of subterranean convulsions. Several of the contortions may also have been produced by lateral movements.

Passage of marine crag into alluvium.—By supposing the adjoining lands to have participated in this movement, we may explain the origin of those masses of an alluvial character which contain the detritus of many rocks, the bones of land animals and of drift timber, which were evidently swept down into the sea. The land-floods which accompany earthquakes are, as we have seen, capable of transporting such materials to great distances †, and, as part of these alluviums must be left somewhere upon the land, we may expect to find, on exploring the interior, a gradual passage from the terrestrial alluvium to that which was carried down into the sea, and which alternates with marine beds.

The fossil quadrupeds imbedded in the crag appear to be the same as those of a great part of the alluviums of the interior

* Dodsley's Annual Register, vol. xv. p. 140. † Vol. i. chap. 25.

of England, which may, therefore, have been formed when the testacea of the older Pliocene period were in existence.

Upon the whole, we may imagine the crag strata to bear a great resemblance to the formations which may now be in progress in the sea between the British and Dutch coasts,—a sea for the most part shallow, yet having here and there a depth of 50 or 60 fathoms, and where strong tides and currents prevail; where shells, also, and zoophytes abound, and where matter drifted from wasting cliffs must be thrown down in certain receptacles in the form of sand, shingle, and mud.

In conclusion we may observe that the history of the crag requires further elucidation, and the author is by no means satisfied with the sketch above given; but as the country is so accessible and the formation so interesting both in its structure and zoological characters, it is hoped that these remarks may excite curiosity and lead to fuller investigation.

Sheppey.—Ramsgate.—Brighton.—Deposits have lately been observed by Mr. Crow * resting on the London clay, in the Isle of Sheppey, at the height of 140 feet above the sea, and by Captain Kater at Pegwell Bay, near Ramsgate, at the height of a few yards, and by Mr. Mantell, in the cliffs near Brighton, all containing recent marine shells. But as there are only five or six species yet discovered in these localities, we cannot decide, till we obtain further information, whether these strata belong to the crag or to a more recent formation.

* Of Christ Church College, Cambridge.

CHAPTER XIV.

Volcanic rocks of the older Pliocene period—Italy—Volcanic region of Olot in Catalonia—Its extent and geological structure—Map—Number of cones—Scoriæ—Lava currents—Ravines in the latter cut by water—Ancient alluvium underlying lava—Jets of air called 'Bufadors'—Age of the Catalonian volcanos uncertain—Earthquake which destroyed Olot in 1421—Sardinian volcanos—District of the Eifel and Lower Rhine—Map—Geological structure of the country—Peculiar characteristics of the Eifel volcanos—Lake craters—Trass—Crater of the Roderberg—Age of the Eifel volcanic rocks uncertain—Brown coal formation.

VOLCANIC ROCKS OF THE OLDER PLIOCENE PERIOD.

Italy.—It is part of our proposed plan to consider the igneous as well as the aqueous formations of each period, but we are far from being able as yet to assign to each of the numerous groups of volcanic origin scattered over Europe a precise place in the chronological series. We have already stated that the volcanic rocks of Tuscany belong, in great part at least, to the older Pliocene period,—those for example of Radicofani, Viterbo, and Aquapendente, which have been chiefly erupted beneath the sea. The same observation would probably hold true in regard to the igneous rocks of the Campagna di Roma.

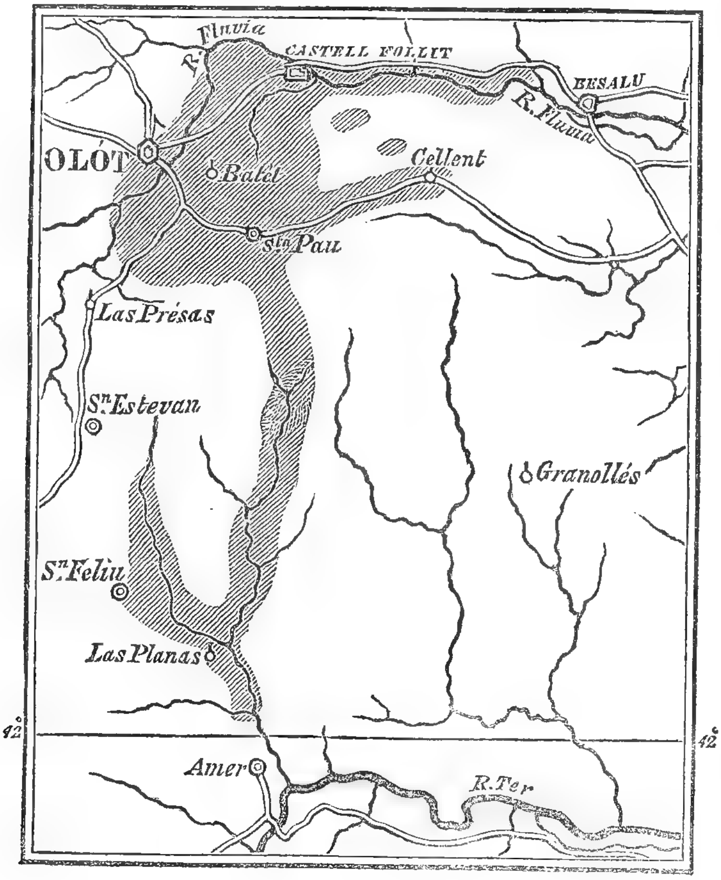
But several other districts, of which the dates are still uncertain, may be mentioned in this chapter as being possibly referrible to the period now under consideration. It will at least be useful to explain to the student the points which require elucidation before the exact age of the groups about to be described can be accurately determined.

Volcanos of Olot, in Catalonia.—I shall first direct the reader's attention to a district of extinct volcanos in the north of Spain, which is little known, and which I visited in the summer of 1830.

The whole extent of country occupied by volcanic products in Catalonia is not more than fifteen geographical miles from

north to south, and about six from east to west. The vents of eruption range entirely within a narrow band running north and south, and the branches which we have represented as extending eastward in the map are formed simply of two lava-streams, those of Castell Follit and Cellent.

No. 43.



Volcanic district of Catalonia.

Dr. Maclure, the American geologist, was the first who made known the existence of these volcanos * ; and, according to his description, the volcanic region extended over twenty square leagues, from Amer to Massanet. I searched in vain in the environs of Massanet, in the Pyrenees, for traces of a lava-current; and I can say with confidence that the adjoined map gives a correct view of the true area of the volcanic action.

* Maclure, Journ. de Phys., vol. lxvi. p. 219, 1808; cited by Daubeny, Description of Volcanos, p. 24.

Geological structure of the district.—The eruptions have burst entirely through secondary rocks, composed in great part of grey and greenish sandstone and conglomerate, with some thick beds of nummulitic limestone. The conglomerate contains pebbles of quartz, limestone, and Lydian stone. The limestone is not only replete with nummulites, but occasionally includes oysters, pectens, and other shells. This system of rocks is very extensively spread throughout Catalonia, one of its members being a red sandstone, to which the celebrated salt-rock of Cardona is subordinate. It is conjectured that the whole belongs to the age of our green-sand and chalk.

Near Amer, in the Valley of the Ter, on the southern borders of the region delineated in the map, primary rocks are seen consisting of gneiss, mica-schist, and clay-slate. They run in a line nearly parallel to the Pyrenees, and throw off the secondary strata from their flanks, causing them to dip to the north and north-west. This dip, which is towards the Pyrenees, is connected with a distinct axis of elevation, and prevails through the whole area described in the map, the inclination of the beds being sometimes at an angle of between 40 and 50 degrees.

It is evident that the physical geography of the country has undergone no material change since the commencement of the era of the volcanic eruptions, except such as has resulted from the introduction of new hills of scoriæ and currents of lava upon the surface. If the lavas could be remelted and poured out again from their respective craters, they would descend the same valleys in which they are now seen, and reoccupy the spaces which they at present fill. The only difference in the external configuration of the fresh lavas would consist in this, that they would nowhere be intersected by ravines, or exhibit marks of erosion by running water.

Volcanic cones and lavas.—There are about fourteen distinct cones with craters in this part of Spain, besides several points whence lavas may have issued; all of them arranged along a narrow line running north and south, as will be seen in the

map. The greatest number of perfect cones are in the immediate neighbourhood of Olot, some of which are represented in the frontispiece, and the level plain on which that town stands has clearly been produced by the flowing down of many lava-streams from those hills into the bottom of a valley, probably once of considerable depth like those of the surrounding country.

In the frontispiece an attempt is made to represent by colours the different geological formations of which the country is composed. The blue line of mountains in the distance are the Pyrenees, which are to the north of the spectator, and consist of primary and ancient secondary rocks. In front of these are the secondary formations described in this chapter, coloured grey. Different shades of this colour are introduced, to express various distances. The flank of the hill, in the foreground, called Costa de Pujou, is composed partly of secondary rocks and partly of volcanic, the red colour expressing lava and scoriæ.

The Fluvia, which passes near the town of Olot, has only cut to the depth of forty feet through the lavas of the plain before mentioned. The bed of the river is hard basalt, and at the bridge of Santa Madalena, are seen two distinct lava-currents, one above the other, separated by a horizontal bed of scoriæ eight feet thick.

In one place, to the south of Olot, the even surface of the plain is broken by a mound of lava, called the 'Bosque de Tosca,' the upper part of which is scoriaceous, and covered with enormous heaps of fragments of basalt more or less porous. Between the numerous hummocks thus formed, are deep cavities, having the appearance of small craters. The whole precisely resembles some of the modern currents of Etna, or that of Côme, near Clermont, the last of which, like the Bosque de Tosca, supports only a scanty vegetation.

Most of the Catalonian volcanos are as entire as those in the neighbourhood of Naples, or on the flanks of Etna. One of these, figured in the frontispiece, called Montsacopa, is of a

very regular form, and has a circular depression or crater at the summit. It is chiefly made up of red scoriæ, undistinguishable from that of the minor cones of Etna. The neighbouring hills of Olivet and Garrinada, also figured in the frontispiece, are of similar composition and shape. The largest crater of the whole district occurs farther to the east of Olot, and is called Santa Margarita. It is 455 feet deep, and about a mile in circumference. Like Astroni, near Naples, it is richly covered with wood, wherein game of various kinds abound.

Although the volcanos of Catalonia have broken out through sandstone, shale, and limestone, as have those of the Eifel, in Germany, to be described in the sequel, there is a remarkable difference in the nature of the ejections composing the cones in these two regions. In the Eifel, the quantity of pieces of sandstone and shale thrown out from the vents, is often so immense as far to exceed in volume the scoriæ, pumice, and lava; but I sought in vain in the cones near Olot for a single fragment of any extraneous rock, and Don Francisco Bolos informs me that he has never been able to detect any. Volcanic sand and ashes are not confined to the cones, but have been sometimes scattered by the wind over the country, and drifted into narrow valleys, as is seen between Olot and Cellent, where the annexed section is exposed. The light cindery volcanic matter rests in thin regular layers, just as it alighted on the slope formed by the solid conglomerate. No flood could have passed through

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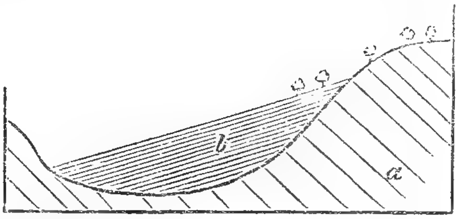

a, Secondary conglomerate. *b*, Thin seams of volcanic sand and scoriæ.

the valley since the scoriæ fell, or these would have been for the most part removed.

The currents of lava in Catalonia, like those of Auvergne, the Vivarais, Iceland, and all mountainous countries, are of considerable depth in narrow defiles, but spread out into com-

paratively thin sheets in places where the valleys widen. If a river has flowed on nearly level ground, as in the great plain near Olot, the water has only excavated a channel of slight depth; but where the declivity is great, the stream has cut a deep section, sometimes by penetrating directly through the central part of a lava-current, but more frequently by passing between the lava and the secondary rock which bounds the valley. Thus, in the accompanying section, at the bridge of Cellent, six miles east of Olot, we see the lava on one side of

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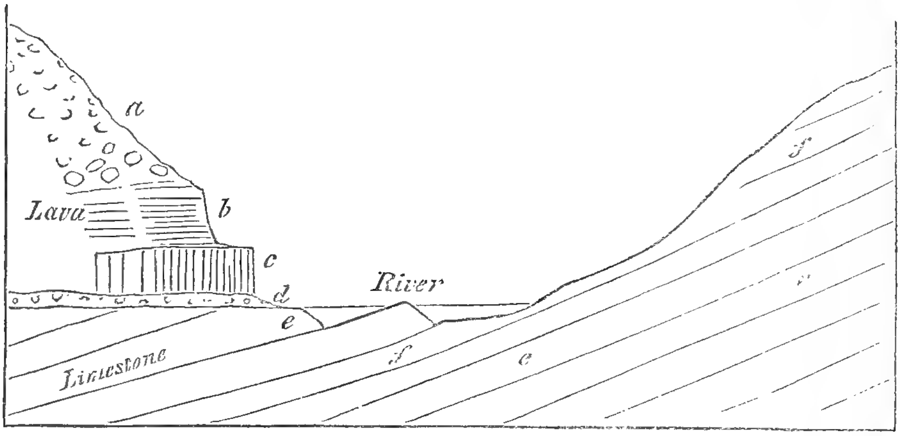


Section above the bridge of Cellent.

a, Scoriaceous lava.
b, Schistose basalt.
c, Columnar basalt.
d, Scoriæ, vegetable soil, and alluvium.
e, Nummulitic limestone.
f, Micaceous grey sandstone.

the small stream, while the inclined stratified rocks constitute the channel and opposite bank. The upper part of the lava at that place is scoriaceous; farther down it becomes less porous, and assumes a spheroidal structure; still lower it divides in horizontal plates, each about two inches in thickness, and is more compact. Lastly, at the bottom is a mass of prismatic basalt about five feet thick. The vertical columns often rest immediately on the subjacent secondary rocks; but there is sometimes an intervention of such sand and scoriæ as cover a country during volcanic eruptions, and which when unprotected, as here, by superincumbent lava, is washed away from the surface of the land. Sometimes the bed *d* contains a few

pebbles and angular fragments of rock; in other places fine earth, which may have constituted an ancient vegetable soil.

In several localities, beds of sand and ashes are interposed between the lava and subjacent stratified rock, as may be seen if we follow the course of the lava-current which descends from Las Planas towards Amer, and stops two miles short of that town. The river there has often cut through the lava, and through eighteen feet of underlying limestone. Occasionally an alluvium, several feet thick, is interposed between the igneous and marine formation; and it is interesting to remark, that in this, as in other beds of pebbles occupying a similar position, there are no rounded fragments of lava, whereas, in the modern gravel beds of rivers in this country, volcanic pebbles are abundant.

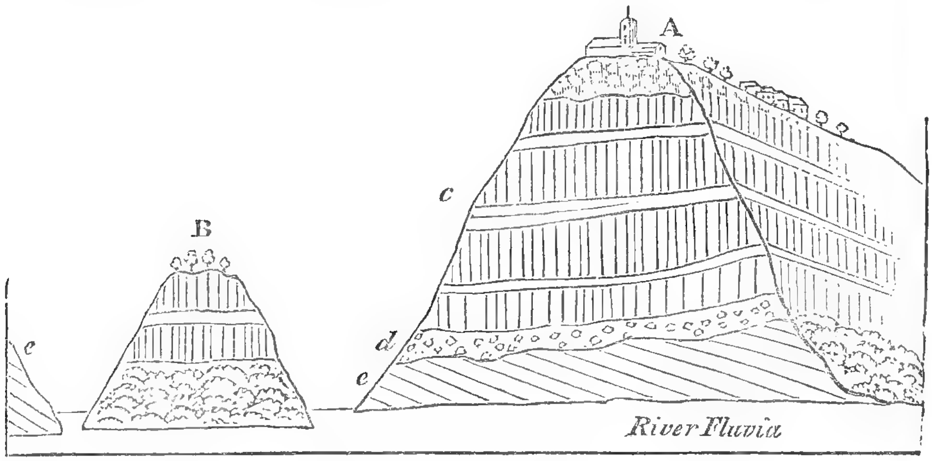
The deepest excavation made by a river through lava, which I observed in this part of Spain, is that seen in the bottom of a valley near San Feliu de Palleróls, opposite the Castell de Stolles. The lava there has filled up the bottom of a valley, and a narrow ravine has been cut through it to the depth of 100 feet. In the lower part the lava has a columnar structure. A great number of ages were probably required for the erosion of so deep a ravine; but we have no reason to infer that this current is of higher antiquity than those of the plain near Olot. The fall of the ground, and consequent velocity of the stream, being in this case greater, a more considerable volume of rock may have been removed in an equal quantity of time.

We shall describe one more section to elucidate the phenomena of this district. A lava-stream, flowing from a ridge of hills to the east of Olot, descends a considerable slope until it reaches the valley of the river Fluvia. Here, for the first time, it comes in contact with running water, which has removed a portion, and laid open its internal structure in a precipice about 130 feet in height, at the edge of which stands the town of Castell Follit.

By the junction of the rivers Fluvia and Teronel the mass of lava has been cut away on two sides; and the insular mass

B (No. 46) has been left, which was probably never so high as the cliff A, as it may have constituted the lower part of the sloping side of the original current.

No. 46.



Section at Castell Follit.

A, Church and town of Castell Follit, overlooking precipices of basalt.
B, Small island, on each side of which branches of the river Teronel flow to meet the Fluvia.
c, Precipice of basaltic lava, chiefly columnar.
d, Ancient alluvium underlying the lava-current.
e, Inclined strata of secondary sandstone.

From an examination of the vertical cliffs, it appears that the upper part of the lava on which the town is built is scoriaceous, passing downwards into a spheroidal basalt; some of the huge spheroids being no less than six feet in diameter. Below this is a more compact basalt with crystals of olivine. There are in all about four distinct ranges of prismatic basalt, separated by thinner beds not columnar, and some of which are schistose. The whole mass rests on alluvium, ten or twelve feet in thickness, composed of pebbles of limestone and quartz, but without any intermixture of igneous rocks; in which circumstance alone it appears to differ from the modern gravel of the Fluvia.

Bufadors.—The volcanic rocks near Olot have often a cavernous structure like some of the lavas of Etna; and in many parts of the hill of Batet, in the environs of the town, the sound returned by the earth, when struck, is like that of an archway. At the base of the same hill are the mouths of

several subterranean caverns, about twelve in number, which are called in the country 'bufadors,' from which a current of cold air issues during summer; but which in winter is said to be scarcely perceptible. I visited one of these bufadors in the beginning of August, 1830, when the heat of the season was unusually intense, and found a cold wind blowing from it, which may easily be explained, for as the external air when rarefied by heat ascends, the cold air from the interior of the mountain rushes in to supply its place.

Age of the Catalonian volcanos uncertain.—It now only remains to offer some remarks on the probable age of these Spanish volcanos. Attempts have been made to prove, that in this country, as well as in Auvergne and the Eifel, the earliest inhabitants were eye-witnesses to the volcanic action. In the year 1421 it is said, when Olot was destroyed by an earthquake, an eruption broke out near Amer, and consumed the town. The researches of Don Francisco Bolos have, I think, shown, in the most satisfactory manner, that there is no good historical foundation for the latter part of this story; and any geologist who has visited Amer must be convinced that there never was any eruption on that spot. It is true that, in the year above-mentioned, the whole of Olot, with the exception of a single house, was cast down by an earthquake; one of those shocks which at distant intervals, during the last five centuries, have shaken the Pyrenees, and particularly the country between Perpignan and Olot, where the movements, at the period alluded to, were most violent.

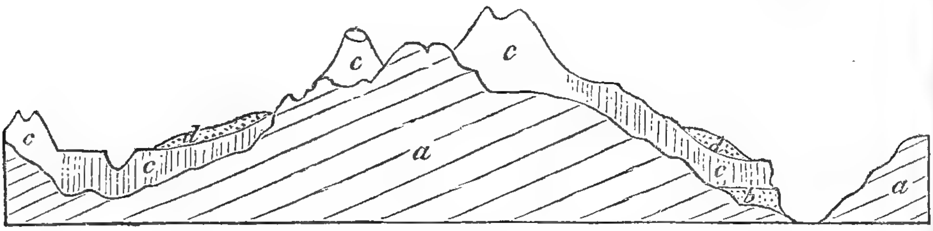
Some houses are said to have sunk into the earth; and this account has been corroborated by the fact that, within the memory of persons now living, the buried arches of a Benedictine monastery were found at a depth of six feet beneath the surface; and still later, some houses were dug out in the street called Aigua. Don Bolos informed me, that he was present when the latter excavation was made, and when the roof of a buried house, nearly entire, was found six feet beneath the surface, the interior being in a great part empty, so that it was

necessary to fill it up with earth and stones, in order to form a sure foundation for the new edifice.

The annihilation of the ancient Olot may, perhaps, be ascribed, not to the extraordinary violence of the movement on that spot, but to the cavernous nature of the subjacent rocks; for Catalonia is beyond the line of those modern European earthquakes which destroy towns throughout extensive areas.

As we have no historical records, then, to guide us in regard to the extinct volcanos, we must appeal to geological monuments. We have little doubt that some fossil land-shells, and bones of quadrupeds, will hereafter reward the industry of collectors. If such remains are found imbedded in volcanic ejections, the period of the eruptions may be inferred; but at present we have no evidence beyond that afforded by superposition, in regard to which the annexed diagram will present to the reader, in a synoptical form, the results obtained from numerous sections.

No. 47.



Superposition of rocks in the volcanic district of Catalonia.

a, Sandstone and nummulitic limestone.
b, Older alluvium with volcanic pebbles.
c, Cones of scoriæ and lava.
d, Newer alluvium.

The more modern alluvium *d* is partial, and has been formed by the action of rivers and floods upon the lava; whereas the older gravel, *b*, was strewed over the country before the volcanic eruptions. In neither have any organic remains been discovered, so that we can merely affirm, as yet, that the volcanos broke out after the elevation of some of the newest rocks of the secondary series, and before the formation of an alluvium, *d*, of unknown date. The integrity of the cones merely shows that the country has not been agitated by violent earth-

quakes, nor subjected to the action of any great transient flood since their origin.

East of Olot, on the Catalonian coast, marine tertiary strata occur, which, near Barcelona, attain the height of about 500 feet. It appears probable, from a small number of shells which I collected, that these strata may correspond with the Sub-apennine beds, so that if the volcanic district had extended thus far, we might be able to determine the age of the igneous products, by observing their relation to these older Pliocene formations *.

Sardinian volcanos.—The line of extinct volcanos in Sardinia, described by Captain Smyth †, is also of uncertain date, as, notwithstanding the freshness of some of the cones and lavas, they may be of high antiquity. They rest, however, on a tertiary formation, supposed by some to correspond to the Sub-apennine strata, but of which the fossil remains have not been fully described.

VOLCANIC ROCKS OF THE EIFEL.

The volcanos of the Lower Rhine and the Eifel are of no less uncertain date than those of Catalonia; but we are desirous of pointing out some of their peculiar characters, and shall, therefore, treat of them in this chapter, trusting that future investigations will determine their chronological relations more accurately.

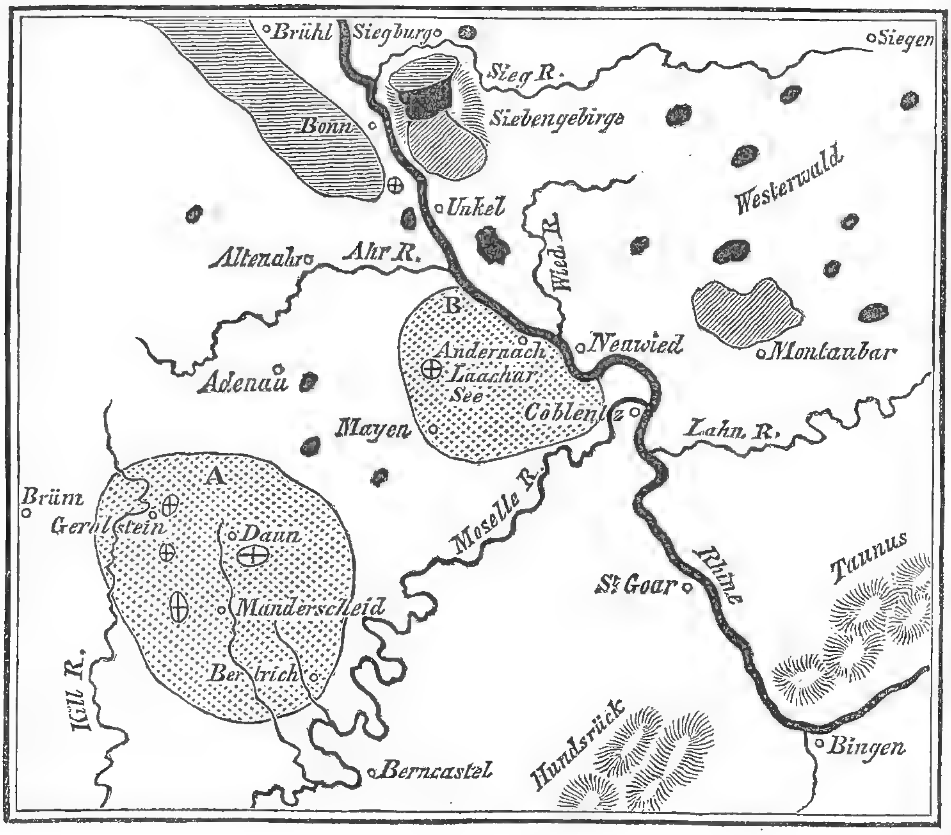
For the geographical details of this volcanic region, we refer the reader to the annexed map, for which I am indebted to Mr. Leonard Horner, whose residence in the country has enabled him to verify the maps of MM. Nöeggerath and Von Oyenhausen, from which that now given has been principally compiled.

* For some account of the Olot volcanos see 'Noticia de Los Estinguidos Volcanes de la Villa de Olot,' by Francisco Bolos. Barcelona. No date,—but the observations, I am told, preceded those of Dr. Maclure.

† Present state of Sardinia, &c., pp. 69, 70.

English Miles.
1 2 3 4 5

No. 48.



Volcanic District } A, Upper Eifel. B, Lower Eifel.

Points of eruption, with craters and scoriæ.

Basalt.

Trachyte.

Brown coal.

N.B. The country in that part of the map which is left blank is almost entirely composed of graywacke.

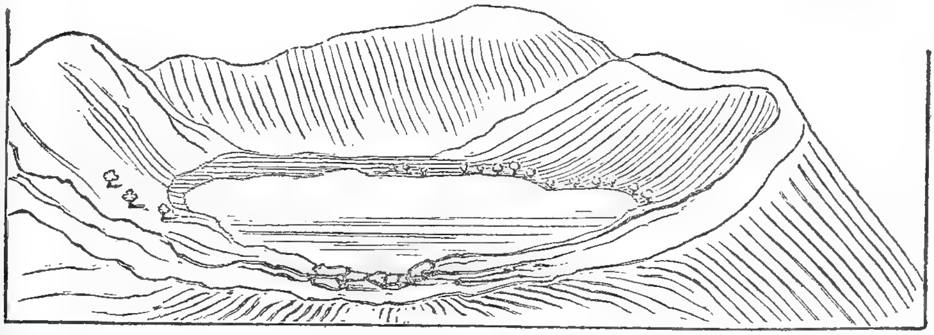
There has been a long succession of eruptions in this country, and some of them must have occurred when its physical geography was in a very different state, while others have happened when the whole district had nearly assumed its present configuration.

The fundamental rock of the Eifel is an ancient secondary sandstone and shale, to which the obscure and vague appellation of 'graywacke' has been given. The formation has precisely the characters of a great part of those grey and red sandstones and shales which are called 'old red sandstone' in

England and Scotland, where they constitute the inferior member of the carboniferous series. In the Eifel they occupy the same geological position, and in some parts alternate with a limestone, containing trilobites and other fossils of our mountain and transition limestones. The strata are inclined at all angles from the horizontal to the vertical, and must have undergone reiterated convulsions before the country was moulded into its present form.

Lake-Craters.—The volcanos have broken out sometimes at the bottom of deep valleys, sometimes on the summit of hills, and frequently on intervening platforms. The traveller often falls upon them unexpectedly in a district otherwise extremely barren of geological interest. Thus, for example, he might arrive at the village of Gemunden, immediately south of Daun, without suspecting that he was in the immediate vicinity of some of the most remarkable vents of eruption. Leaving a stream which flows at the bottom of a deep valley in a sandstone country, he climbs the steep acclivity of a hill where he observes the edges of strata of sandstone and shale dipping inwards towards the mountain. When he has ascended to a considerable height he sees fragments of scoriæ sparingly scattered over the surface, till at length on reaching the summit he finds himself suddenly on the edge of a *tarn*, or deep circular lake-basin.

No. 49.

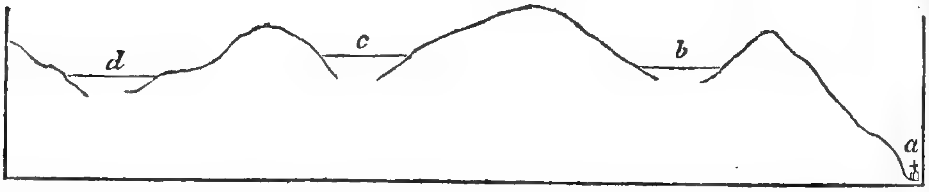


The Gemunden Maar.

This, which is called the Gemunden Maar, is the first of three lakes which are in immediate contact, the same ridge forming the barrier of two neighbouring cavities (see diag. No. 50). On

viewing the first of these we recognize the ordinary form of a crater, for which we have been prepared by the occurrence of

No. 50.



a, Village of Gemunden. *c*, Weinfelder Maar.
b, Gemunden Maar. *d*, Schalkenmehren Maar.

scoriæ scattered over the surface of the soil. But on examining the walls of the crater, we find precipices of sandstone and shale which exhibit no signs of the action of heat, and we look in vain for those beds of lava and scoriæ, dipping in opposite directions on every side, which we have been accustomed to consider as characteristic of volcanic craters. As we proceed, however, to the opposite side of the lake, and afterwards visit the craters *c* and *d*, we find a considerable quantity of scoriæ and some lava, and see the whole surface of the soil sparkling with volcanic sand and ejected fragments of half-fused shale, which preserves its laminated texture in the interior, while it has a vitrified or scoriform coating.

We cannot, therefore, doubt that these great hollows have been formed by gaseous explosions; in other words, that parts of the summits of hills composed of sandstone and shale were blown up during a copious discharge of gas or steam, accompanied by the escape of a small quantity of lava. It is a peculiar feature of the Eifel volcanos that aëriform discharges have been violent, and the quantity of melted matter poured out from the vents proportionably insignificant. In this respect they differ, as a group, from any assemblage of extinct volcanos which I have seen in France, Italy, or Spain.

In some of the Eifel lavas, as in Auvergne and the Vivarais, fragments of granite, gneiss, and clay-slate are found inclosed; pieces of these rocks having probably been torn off by the melted matter and gases as they rose from below.

A few miles to the south of the lakes above-mentioned

occurs the Pulvermaar of Gillenfeld, an oval lake of very regular form, and surrounded by an unbroken ridge of fragmentary materials, consisting of ejected shale and sandstone, and preserving an uniform height of about one hundred and fifty feet above the water. The side slope in the interior is at an angle of about 45°; on the exterior, of 35°. Volcanic substances are intermixed very sparingly with the ejections which in this place entirely conceal from view the stratified rocks of the country *.

The Meerfelder Maar is a cavity of far greater size and depth, hollowed out of similar strata; the sides presenting some abrupt sections of inclined secondary rocks, which in other places are buried under vast heaps of pulverised shale. I could discover no scoriæ amongst the ejected materials, but balls of olivine, and other volcanic substances are mentioned as having been found †. This cavity, which we must suppose to have discharged an immense volume of gas, is nearly a mile in diameter, and is said to be more than one hundred fathoms deep. In the neighbourhood is a mountain called the Moseberg, which consists of red sandstone and shale in its lower parts, but supports on its summit a triple volcanic cone, while a distinct current of lava is seen descending the flanks of the mountain. The edge of the crater of the largest cone reminded me much of the form and characters of that of Vesuvius.

If we pass from the Upper to the Lower Eifel we find the celebrated lake-crater of Laach, which has a greater resemblance than any of those before-mentioned to the Lago di Bolsena, and others in Italy—being surrounded by a ridge of gently sloping hills, composed of loose tuffs, scoriæ, and blocks of a variety of lavas.

Trass and its origin.—It appears that in the Lower Eifel eruptions of trachytic lava preceded the emission of currents of basalt, and that immense quantities of pumice were thrown out wherever trachyte issued. In this district, also, we find

* Scrope, Edin. Journ. of Sci., June 1826, p. 145.

† Hibbert, Extinct Volcanos of the Rhine, p. 24.

the tufaceous alluvium of the Rhine volcanos called *trass*, which has covered large areas, and choked up some valleys now partially re-excavated. This trass is, like the loess, unstratified. The base is composed almost entirely of pumice, in which are included fragments of basalt and other lavas, pieces of burnt shale, slate, and sandstone, and numerous trunks and branches of trees.

If an eruption, attended by a copious evolution of gases, should now happen in one of the lake basins, we might suppose the water to remain for weeks in a state of violent ebullition, until it became of the consistency of mud, just as the sea became charged with red mud round the new island of Sciacca, in the Mediterranean, in the year 1831. If a breach should then be made in the side of the cone, the flood would sweep away great heaps of ejected fragments of shale and sandstone, which would be borne down into the adjoining valleys. Forests would be torn up by such a flood, which would explain the occurrence of the numerous trunks of trees dispersed irregularly through the trass.

Crater of the Roderberg.—One of the most interesting volcanos on the left bank of the Rhine is called the Roderberg. It forms a circular crater nearly a quarter of a mile in diameter, and one hundred feet deep, now covered with fields of corn. The highly inclined graywacke strata rise even to the rim of one side of the crater, but they are overspread by quartzose gravel, and this again is covered by volcanic scoriæ and tufaceous sand. The opposite wall of the crater is a scoriaceous rock, like that at the summit of Vesuvius. It is quite evident that the eruption in this case burst through the graywacke and alluvium which immediately overlies it; and I observed some of the quartz pebbles mixed with scoriæ on the flanks of the mountain, so placed as if they had been cast up into the air, and had fallen again with the volcanic ashes.

On the opposite, or right bank of the Rhine, are the Siebengebirge, a group of mountains wherein analogous phenomena are exhibited. There also trachytic lavas have flowed out and

covered the graywacke; and basaltic currents of a somewhat later date have followed.

There is, however, such a connexion between these rocks that a suite might be procured from the Siebengebirge, showing an insensible gradation from highly crystalline trachyte into compact basalt, with the accompanying passage of the hornblende in the former, into augite in the latter.

Age of the volcanic rocks of the Eifel uncertain.—Besides the ancient inclined graywacke, we have in the immediate vicinity of the valley of the Rhine, a nearly horizontal tertiary formation, called brown coal, from the association with it of beds of lignite worked for coal. The great mass of the igneous rocks are seen to be newer than this formation; and thus we obtain a relative date of much local importance for the volcanos of the whole region. This brown coal consists of beds of sand and sandstone, with nodules of clay-ironstone, and siliceous conglomerate. Beds of lignite of various thickness are interstratified with the clays and sands, and often irregularly diffused through them. This deposit was classed with the plastic clay at a time when every group of tertiary strata was referred to the age of some one of the subdivisions of the Paris basin, but as no shells, either marine, fresh-water, or land have yet been found imbedded, it is not easy to decide the age of the formation. Near Marienforst, in the vicinity of Bonn, large blocks are found on the surface of a white opaque quartz rock, containing numerous casts of fresh-water shells which appear to belong to *Planorbis rotundatus* and *Limnea longiscatus,* two well-known Eocene species*; but this rock is not in situ, and may possibly have been a local deposit in some small lake, fed by a spring holding silica in solution. Yet, as there are beds of the brown coal at Marienforst, and this formation contains in other places subordinate beds of silex, it seems to me most probable that the quartzose blocks alluded to were derived from some member of that tertiary group.

* M. Deshayes, to whom I showed the specimens, said he felt as confident of the above identifications as *mere casts* would warrant.

The other organic remains of the brown coal are principally fishes; they are found in a bituminous shale, called paper-coal, from being divisible into extremely thin leaves. The individuals are extremely numerous, but they appear to belong to about five species, which M. Agassiz informs me are all extinct, and hitherto peculiar to the brown coal. They belong to the fresh-water genera Leuciscus, Aspius, and Perca. The remains of frogs also, of an extinct species, have been discovered in the paper coal, and a perfect series may be seen in the museum at Bonn, from the most imperfect state of the tadpole to that of the full-grown animal. With these a salamander, scarcely distinguishable from the recent species, has been found.

All the distinguishable remains of plants in the lignite and associated beds are said to belong to dicotyledonous trees and shrubs, bearing a close resemblance to those now existing in the country. The same is declared to be the case with the remains found in the trachytic tuffs and in the trass; but the absolute identification of species on which some geologists have insisted must be received with great caution.

As trachytic tuff has been observed at several places interstratified with the clay beds of the brown coal formation, and containing the same impressions of plants, there can be no doubt that the oldest eruptions began when the fresh-water deposits were still in progress, and when the geographical features of the country must have been extremely different from those which it has now assumed.

We have stated that the volcanic ejections of the Roderberg repose upon a bed of gravel. This gravel forms part of an ancient alluvium which is quite distinct in character from that now found in the plains of the valley of the Rhine. It consists chiefly of quartz pebbles, and is found at considerable elevations both on the graywacke and brown coal beds. It forms indeed a general capping to the latter, varying from ten to thirty-five feet in thickness, and was probably an alluvium formed at that period when the ancient lake, in which the

brown coal strata were deposited, was drained; for the disappearance of that great body of fresh water may naturally be supposed to have taken place when the country was undergoing great changes in its physical geography.

Beds and large veins of quartz are found in the Hundsruck, Taunus, and Eifel, the nearest mountain-chains which border this part of the Rhine, and their degradation may have supplied the quartz found in this gravel called *Kiesel gerolle* by the Germans.

It has been supposed by some writers that the *latest* volcanic eruptions of the Eifel and Rhine coincided in epoch with the deposition of the Loess before described (chap. xi.). Such an association, if established, would give a comparatively recent date to the most modern igneous eruptions; but I looked in vain for any clear indications of such a connexion, and all the sections which I saw appeared to indicate the posteriority of the Loess. The integrity of the volcanic cones is, for reasons before explained, a character to which we attach no value.

We have, therefore, in this region, graywacke covered by brown coal, and some volcanic formations so blended with the latter as to prove the igneous eruptions to have been contemporaneous. Yet when we endeavour to assign a chronological position to any one part of the series by reference to organic remains, we discover that the evidence is vague and inconclusive. I have as yet been unable to obtain satisfactory proof that any one species of fossil animal or plant has been found in the brown coal, or superimposed formations which was common to a tertiary group of known date in any other part of Europe; whereas the reader will bear in mind that the relative age of different tertiary formations, of which we have before spoken, was usually determined by reference to a comparison of several hundred, often more than a thousand, species of testacea*.

* A memoir has lately been communicated to the Geological Society of London, by Mr. Horner, on the geology of this district. For fuller details consult Nöeggerath's Rheinland Westphalen, and the works of Von Dechen, Oyenhausen, Von Buch, Steininger, Van der Wyck, Scrope, Daubeny, Leonhard, and Hibbert.

CHAPTER XV.

Miocene period—Marine formations—Faluns of Touraine—Comparison of the Faluns of the Loire and the English Crag—Basin of the Gironde and Landes—Fresh-water limestone of Saucats—Position of the limestone of Blaye—Eocene strata in the Bordeaux basin—Inland cliff near Dax—Strata of Piedmont—Superga—Valley of the Bormida—Molasse of Switzerland—Basin of Vienna—Styria—Hungary—Volhynia and Podolia—Montpellier.

MIOCENE FORMATIONS—MARINE.

Having treated in the preceding chapters of the older and newer Pliocene formations, we shall next consider those members of the tertiary series which we have termed Miocene. The distinguishing characters of this group, as derived from its imbedded fossil testacea, have been explained in the fifth chapter (p. 54). In regard to the relative *position* of the strata, they underlie the older Pliocene, and overlie the Eocene formations, when any of these happen to be present.

The area covered by the marine, fresh-water, and volcanic rocks of the Miocene period, in different parts of Europe, can already be proved to be very considerable, for they occur in Touraine, in the basin of the Loire, and still more extensively in the south of France, between the Pyrenees and the Gironde. They have also been observed in Piedmont, near Turin, and in the neighbouring valley of the Bormida, where the Apennines branch off from the Alps. They are largely developed in the neighbourhood of Vienna and in Styria; they abound in parts of Hungary; and they overspread extensive tracts in Volhynia and Podolia.

Shells characteristic of the Miocene strata are found in all these countries, figures of some of which are given in Plate 2 in this volume. They characterize the period, because they are either wanting or extremely rare in the Eocene or Pliocene formations.

We shall now proceed to notice briefly some of the countries

before enumerated as containing monuments of the era under consideration.

Touraine.—We have already alluded to the proofs of superposition adduced by M. Desnoyers, to show that the shelly strata provincially called 'the Faluns of the Loire' were posterior to the most recent fresh-water formation of the basin of the Seine. Their position, therefore, shows that they are of newer origin than the Eocene strata,—more recent, at least, than the uppermost beds of the Paris basin. But an examination of their fossil contents proves also that they are referrible to that type which distinguishes the Miocene period. When three hundred of the Touraine shells were compared with more than eleven hundred of the Parisian species, there were scarcely more than twenty which could be identified; and, on the other hand, the fossil shells of the Touraine beds agree far less with the testacea now inhabiting our seas than does the group occurring in the older Pliocene strata of northern Italy.

The Miocene strata of the Loire have been observed to repose on a great variety of older rocks between Sologne and the sea, in which line they are seen to rest successively upon gneiss, clay-slate, coal-measures, Jura limestone, greenstone, chalk, and lastly upon the upper fresh-water deposits of the basin of the Seine. They consist principally of quartzose gravel, sand, and broken shells. The beds are generally incoherent, but sometimes agglutinated together by a calcareous or earthy cement, so as to serve as a building-stone. Like the shelly portion of the crag of Norfolk and Suffolk, the *faluns* and associated strata are of slight thickness, not exceeding seventy feet. They often bear a close resemblance to the crag in appearance, the shells being stained of the same ferruginous colour, and being in the same state of decay; serving in Touraine, just as in Norfolk and Suffolk, to fertilize the arable land. Like the crag, also, they contain mammiferous remains, which are not only intermixed with marine shells, but sometimes encrusted with serpulæ, flustra, and balani. These

terrestrial quadrupeds belong to the genera Mastodon, Rhinoceros, Hippopotamus, &c., the assemblage, considered as a whole, being very distinct from those of the Paris gypsum.

I examined several detached patches of the Touraine beds, where they rest on primary strata in the environs of Nantes, particularly one locality at Les Cleons, about eight miles south-east of that town, and was struck with the evidence afforded by them of the emergence of large intervening tracts of granitic schist since the Miocene era, which we might otherwise have supposed to have been raised at a very remote epoch. It is probable that these patches of tertiary deposits were originally local, having been thrown down wherever the set of the tides and currents permitted an accumulation to take place.

The faluns and contemporary strata of the basin of the Loire may be considered generally as having been formed in a shallow sea, into which a river, flowing perhaps from some of the lands now drained by the Loire, introduced from time to time fluviatile shells, wood, and the bones of quadrupeds, which may have been washed down during floods. Some of these bones have precisely the same black colour as those found in the peaty shell-marl of Scotland; and we might imagine them to have been dyed black in *Miocene peat* which was swept down into the sea during the waste of cliffs, did we not find the remains of cetacea in the same strata, bones, for example, of the lamantine, morse, sea-calf, and dolphin, having precisely the same colour.

Comparison of the Faluns of the Loire and the English Crag.—The resemblance which M. Desnoyers has pointed out as existing between the English *crag* and the French *faluns* is one which ought by no means to induce us to ascribe a contemporaneous origin to these two groups, but merely a similarity of geographical circumstances at the respective periods when each was deposited. In every age, where there is land and sea, there must be shores, shallow estuaries, and rivers; and near the sea-coasts banks of marine shells and corals may accumulate. It must also be expected that rivers will drift in

fresh-water shells, together with sand and pebbles, and occasionally, perhaps, sweep down the carcasses of land quadrupeds into the sea. If the sand and shells, both of the 'crag' and the 'faluns' have each acquired the same ferruginous colour, such a coincidence would merely lead us to infer that, at each period, there happened to be springs charged with iron, which flowed into some part of the sea or basin of the river, by which the sediment was carried down into the sea.

Even had the French and English strata which we are comparing shared a greater number of mineral characters in common, that identity could not have justified us in inferring the synchronous date of the two groups, where the discordance of fossil remains is so marked. The argument which infers a contemporaneous origin from correspondence of mineral contents, proceeds on the supposition that the materials were either washed down from a common source, or from different sources into a common receptacle. If, according to the latter hypothesis, the crag and the faluns were thrown down in one continuous sea, the testacea could not have been so distinct in two very contiguous regions, unless we assume that the laws which regulated the geographical distribution of species were then distinct from those now prevailing. But if it be said that the two basins may have been separated from each other, as are those of the Mediterranean and Red Sea, by an isthmus, and that distinct assemblages of species may have flourished in each, as in the example above-mentioned is actually the case *, we may reply that such narrow lines of demarcation are extremely rare now, and must have been infinitely more so in remoter tertiary epochs, because there can be no doubt that the proportion of land to sea has been greatly on the increase in European latitudes during the more modern geological eras.

In the *faluns*, and in certain groups of the same age, which occur not far to the west of Orleans, M. Desnoyers has discovered the following mammiferous quadrupeds. *Palæothe-*

* See above, chap. x.

rium magnum, *Mastodon angustidens*, *Hippopotamus major*, and *H. minutus*, *Rhinoceros leptorhinus*, and *R. minutus*, *Tapir gigas*, *Anthracotherium* (small species), *Sus*, *Equus* (small species), *Cervus*, and an undetermined species of the Rodentia.

The first species on this list is common to the Paris gypsum, and is therefore an example of a land quadruped common to the Miocene and Eocene formations, an exception perfectly in harmony with the results obtained from the study of fossil shells *.

Basin of the Gironde and district of the Landes.—A great extent of country between the Pyrenees and the Gironde is overspread by tertiary deposits which have been more particularly studied in the environs of Bordeaux and Dax, from whence about 600 species of shells have been obtained. These shells belong to the same type as those of Touraine.—See Appendix I.†

Most of the beds near Dax, whence these shells are procured, consist of incoherent quartzose sand, mixed for the most part with calcareous matter, which has often bound together the sand into concretionary nodules. A great abundance of fluviatile shells occur in many places intermixed with the marine; and in some localities microscopic shells are in great profusion.

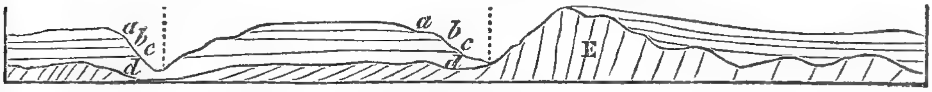
The tertiary deposits in this part of France are often very inconstant in their mineralogical character, yet admit generally of being arranged in four groups, which are enumerated in the explanation of diagram No. 51.

In some places the united thickness of these groups is considerable, but in the country between the Pyrenees and the valley of the Adour around Dax, the disturbed secondary rocks

* For further details respecting the basin of the Loire, see M. Desnoyers, Ann. des Sci. Nat., tome xvi. pp. 171 and 402, where full references to other authors are given.

† M. de Basterot has given a description of more than 300 shells of Bordeaux and Dax, and figures of the greater number of them. Mém. de la Soc. d'Hist. Nat. de Paris, tome ii.

are often covered by a thin pellicle only of tertiary strata, which rests horizontally on the chalk and does not always conceal it.



Tertiary strata overlying chalk in the environs of Dax.

a, Siliceous sand without shells. *c,* Sand and marl with shells.
b, Gravel. *d,* Blue marl with shells.
E, Chalk and volcanic tuff.

In the valleys of the Adour and Luy, sections of all the members of the tertiary series are laid open, but the lowest blue marl, which is sometimes 200 feet thick, is not often penetrated. On the banks of the Luy, however, to the south of Dax, the subjacent white chalk is exposed in inclined and vertical strata. In the hill called Puy Arzet the chalk, characterized by its peculiar fossils, is accompanied by beds of volcanic tuff, which are conformable to it, and which may be considered as the product of submarine eruptions which took place in the sea wherein the chalk was formed.

About a mile west of Orthès, in the Bas Pyrenees, the blue marl is seen to extend to the borders of the tertiary formation, and rises to the height probably of six or seven hundred feet. In that locality many of the marine Miocene shells preserve their original colours. This marl is covered by a considerable thickness of ferruginous gravel, which seems to increase in volume near the borders of the tertiary basin on the side of the Pyrenees.

In an opposite direction, to the north of Dax, the shelly sands often pass into calcareous sandstone, in which there are merely the casts of shells as at Carcares, and into a shelly breccia resembling some rocks of recent origin which I have received from the coral reefs of the Bermudas.

Fresh-water limestone at Saucats.—Associated with the Miocene strata near Bordeaux, at a place called Saucats, is a

compact fresh-water limestone, of slight thickness, which is perforated on the upper surface by marine shells, for the most part of extinct species. It is evident that the space must have been alternately occupied by salt and fresh water. First, a lagoon may have been formed, in which the water may have become fresh; then a barrier of sand, by which the sea was excluded for a time, may have been breached, whereby the salt water again obtained access.

Eocene strata in the Bordeaux basin.—The relations of some of the members of the tertiary series, in the basin of the Gironde, have of late afforded matter of controversy. A limestone, resembling the calcaire grossier of Paris, and from 100 to 200 feet in thickness, occurs at Pauliac and Blaye, and extends on the right bank of the Gironde, between Blaye and La Roche. It contains many species of fossils identical with those of the Paris basin. This fact was pointed out to me by M. Deshayes before I visited Blaye in 1830; but although I recognized the mineral characters of the rock to be very different from those of the Miocene formations in the immediate neighbourhood of Bordeaux, I had not time to verify its relative position. I inferred, however, the inferiority of the Blaye limestone to the Miocene strata, from the order in which each series presented itself as I receded from the chalk and passed to the central parts of the Bordeaux basin.

Upon leaving the white chalk with flints, in travelling from Charente by Blaye to Bordeaux, I first found myself upon overlying red clay and sand (as at Mirambeau); I then came upon the tertiary limestone above alluded to, at Blaye; and lastly, on departing still farther from the chalk, reached the strata which at Bordeaux and Dax contain exclusively the Miocene shells.

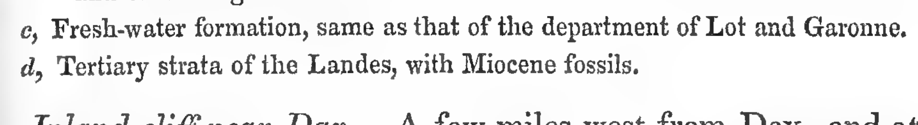
The occurrence both of Eocene and Miocene fossils in the same basin of the Gironde, had been cited by M. Boué as a fact which detracted from the value of zoological characters as a means of determining the chronological relations of tertiary

groups. But on farther inquiry, the fact, on the contrary, has furnished additional grounds of confidence in these characters.

M. Ch. Desmoulins replied, in answer to M. Boué's objections, that the assemblage of Eocene shells are never intermixed with those found in the 'moellon,' as he calls the sandy calcareous rock of the environs of Bordeaux and Dax; and M. Dufrénoy farther stated, that the hills of limestone which border the right bank of the Gironde, from Marmande as far as Blaye, present several sections wherein the Parisian (or Eocene) limestone is seen to be separated from the shelly strata called 'faluns,' or 'moellon,' by a fresh-water formation of considerable thickness. It appears, therefore, that as the marine faluns of Touraine rest on a fresh-water formation, which overlies the marine calcaire grossier of Paris, so the marine Miocene strata of Bordeaux are separated from those of Blaye by a fresh-water deposit *.

The following diagram, therefore, will express the order of position of the groups above alluded to.

No. 52.



a, Red clay and sand.

b, Limestone like calcaire grossier, sometimes alternating with green marl and containing Eocene shells.

c, Fresh-water formation, same as that of the department of Lot and Garonne.

d, Tertiary strata of the Landes, with Miocene fossils.

Inland cliff near Dax.—A few miles west from Dax, and at the distance of about twelve miles from the sea, a steep bank is seen running in a direction nearly north-east and south-west, or parallel to the contiguous coast. This steep declivity, or *brae*, which is about 50 feet in height, conducts us from the higher platform of the Landes to a lower plain which extends to the sea. The outline of the ground might suggest to every geologist the opinion, that the bank in question was once

* Bulletin de la Soc. Géol. de France, tome ii. p. 440.

a sea-cliff, when the whole country stood at a lower level

No. 53.

Section of Inland cliff at Abesse, near Dax.

a, Sand of the Landes. *b*, Limestone. *c*, Clay.

relatively to the sea. But this can no longer be regarded as matter of conjecture. In making excavations recently for the foundation of a building at Abesse, a quantity of loose sand, which formed the slope *d*, *e*, was removed, and a perpendicular cliff exposed about 50 feet in height. The bottom of this cliff consists of limestone, *b*, which contains shells and corals of Miocene species, and is probably a calcareous form of the division *c* (diagram No. 51, p. 207). Immediately below this limestone is the clay *c* (probably *d*, diagram No. 51, p. 207), and above it the usual tertiary sand *a* of the department of the Landes. At the base of the precipice are seen large, partially-rounded, masses of rock, evidently detached from the stratum *b*. The face of the limestone is hollowed out and weathered into such forms as are seen in the calcareous cliffs of the adjoining coast, especially at Biaritz, near Bayonne*. It is evident that, when the country was at a somewhat lower level, the sea advanced along the surface of the argillaceous stratum *c*, which, by its yielding nature, favoured the waste and undermining of the more solid superincumbent limestone *b*. Afterwards, when the country had been elevated, part of the sand *a* fell down, or was drifted by the winds, so as to form the talus *d*, *e*, which masked the inland cliff until it was artificially laid open to view.

The situation of this cliff is interesting, as marking one of the pauses which intervened between the successive movements of elevation whereby the marine tertiary strata of this country

* This spot was pointed out to me by the proprietor of the lands of Abesse in 1830.

were upheaved to their present height, a pause which allowed time for the sea to advance and strip off the upper beds *a*, *b*, from the denuded clay *c*.

Hills of Mont Ferrat and the Superga.—The late Signor Bonelli of Turin was the first who remarked that the tertiary shells found in the green sand and marl of the Superga near Turin differed, as a group, from those generally characteristic of the Subapennine beds. The same naturalist had also observed, that many of the species peculiar to the Superga were identical with those occurring near Bordeaux and Dax. The strata of which the hill of the Superga is composed, are inclined at an angle of more than 70 degrees. They consist partly of fine sand and marl, and partly of a conglomerate composed of primary boulders, which forms a lower part of the series, and not, as represented by M. Brongniart by mistake *, an unconformable and overlying mass †. This same series of beds is more largely developed in the chain of Mont Ferrat, especially in the basin of the Bormida. The high road which leads from Savona to Alessandria intersects them in its northern descent, and the formation may be well studied along this line at Carcare, Cairo, and Spinto, at all which localities fossil shells occur in a bright green sand. At Piana, a conglomerate, interstratified with this green sand, contains rounded blocks of serpentine and chlorite schist, larger than those near the summit of the Superga, some of the blocks being not less than nine feet in diameter.

When we descend to Aqui, we find the green sand giving place to bluish marls, which also skirt the plains of the Tanaro at lower levels. These newer marls are associated with sand, and are nearly horizontal, and appear to belong to the older Pliocene Subapennine strata ‡. The shells which characterize the latter, abound in various parts of the country near Turin; but that region has not yet been examined with sufficient care to enable us to give exact sections to illustrate the superpo-

* Terrains du Vicentin, p. 26.

† I examined the Superga in company with Mr. Murchison in 1828.

‡ See section, wood-cut No. 4, p. 21.

P 2

sition of the Miocene and older Pliocene beds. It is, however, ascertained, that the highly-inclined green sand, which comes immediately in contact with the primary rocks, is the oldest part of the series *.

Molasse of Switzerland.—If we cross the Alps, and pass from Piedmont to Savoy, we find there, at the northern base of the great chain and throughout the lower country of Switzerland, a soft green sandstone, much resembling some of the beds of the basin of the Bormida, above described, and associated in a similar manner with marls and conglomerate. This formation is called, in Switzerland, 'molasse,' said to be derived from 'mol,' '*soft,*' because the stone is easily cut in the quarry. It is of vast thickness, but shells have so rarely been found in it that they do not supply sufficient data for correctly determining its age. M. Studer, in his treatise on the 'molasse,' enumerates some fossil shells found near Lucerne, agreeing, apparently, with the testacea of the Subapennine hills. The correspondence in mineral character between the green sand of Piedmont and that of Switzerland can in nowise authorise us to infer identity of age, but merely to conclude that both have been derived from the degradation of similar ancient rocks.

Until the place of the 'molasse' in the chronological series of tertiary formations has been more rigorously determined, the application of this provincial name to the tertiary groups of other countries must prove a source of ambiguity, and we regret that the term has been so vaguely employed by M. Boué.

Styria, Vienna, Hungary, &c.—Of the various groups which have hitherto been referred to the Miocene era, none are so important in thickness and geographical extent as those which are found at the eastern extremity of the Alps, in what have been termed the basins of Vienna and Styria, and which spread thence into the plains of Hungary. The collection of shells formed by M. Constant Prevost, in the neighbourhood of

* We trust that MM. Pareto, Passini, Sismonda, and La Marmora, will devote their attention to the relative position of the several groups of tertiary strata in Piedmont, by instituting a comparison between their respective organic remains.

Vienna, and described by him in 1820*, were alone sufficient to identify a great part of the formations of that country with the Miocene beds of the Loire, Gironde, and Piedmont. The fossil remains subsequently procured by that indefatigable observer M. Boué have served to show the still greater range of the same beds through Hungary and Transylvania.

It appears from the recently published memoirs of Professor Sedgwick and Mr. Murchison†, that the formations in Styria may be divided into groups corresponding to those adopted by M. Partsch for the Vienna beds; the basin of Vienna exhibiting nearly the same phenomena as that of Styria. These regions have evidently formed, during the Miocene period, two deep bays of the same sea, separated from each other by a great promontory connected with the central ridge of the eastern Alps.

The English geologists, above mentioned, describe a long succession of marine strata intervening between the Alps and the plains of Hungary, which are divisible into three natural groups, each of vast thickness, and affording a great variety of rocks. All these groups are of marine origin, and lie in nearly horizontal strata, but have a slight prevailing easterly dip, so that, in traversing them from west to east, we commence with the oldest and end with the youngest beds. At their western extremity they fill an irregular trough-shaped depression, through which the waters of the Mur, the Raab, and the Drave, make their way to the lower Danube‡. They here consist of conglomerate, sandstone, and marls, some of the marls containing marine shells. Beds also of lignite occur, showing that wood was drifted down in large quantities into the sea. In parts of the series there are masses of rounded siliceous pebbles resembling the shingle banks which are forming on some of our coasts.

The second principal group is characterized by coralline

* Journal de Physique, Novembre, 1820.

† Geol. Trans., Second Series, vol. iii. p. 301.

‡ Ibid., p. 382.

and concretionary limestone of a yellowish white colour: it is finely exposed in the escarpments of Wildon, and in the hills of Ehrenhausen, on the right bank of the Mur*. This coralline limestone is not less than 400 feet thick at Wildon, and exceeds, therefore, some of the most considerable of our secondary groups in England, as, for example, the 'Coral Rag†.'

Beds of sandstone, sand, and shale, and calcareous marls, are associated with the above-mentioned limestone.

The third group, which occurs at a still greater distance from the mountains, is composed of sandstone and marl, and of beds of limestone, exhibiting here and there a perfectly oolitic structure. In this system fossil shells are numerous.

It is by no means clear that the coralline limestones of the second group, are posterior in origin to all the beds of the first division; they may possibly have been formed at some distance from land, while the head of the gulf was becoming filled up with enormous deposits of gravel, sand, and mud, which may, in that quarter, have rendered the waters too turbid for the fullest development of testaceous and coralline animals.

In regard to the age of the formations above described, we may observe that the middle group, both in the basins of Styria and Vienna, belongs indisputably to the Miocene period, for the species of shells are the same as those of the Loire, Gironde, and other contemporary basins before noticed. Whether the lowest and uppermost systems are referrible to the same, or to distinct tertiary epochs, is the only question. We cannot doubt that the accumulation of so vast a succession of beds required an immense lapse of ages, and we are prepared to find some difference in the species characterizing the different members of the series; nevertheless, all may belong to different subdivisions of the Miocene period. Professor Sedgwick and Mr. Murchison have suggested that the inferior, or first group, which comprises the strata between the Alps and the coralline

* Geol. Trans., Second Series, vol. iii. p. 385. † Ibid., p. 390.

limestone of Wildon, may correspond in age to the Paris basin; but the list of fossils which they have given, seems rather to favour the supposition, that the deposit is of the Miocene era. They enumerate four characteristic Miocene fossils,—Mytilus Brardii, Cerithium pictum, C. pupæforme, and C. plicatum,—and if there are some few of the associated shells common to the Paris basin, such a coincidence is no more than holds true in regard to all the European Miocene formations.

On the other hand, the third or newest system, which overlies the coralline limestone, contains fossils which do not appear to depart so widely from the Miocene type as to authorize us to separate them. They appear to agree with the tertiary strata of a great part of Hungary and Transylvania, which will be seen, by the tables of shells in Appendix I., to be referrible to the Miocene period.

Volhynia and Podolia.—We may expect to find many other districts in Europe composed of Miocene strata, and there appears already to be sufficient evidence that the marine deposits of the platform of Volhynia and Podolia were of this era. The fossils of that region, which is bounded by Galicia on the west, and the Ukraine on the east, and comprises parts of the basins of the Bog and the Dniester, has been investigated by Von Buch, Eichwald, and Du Bois, and the latter has given excellent plates of more than one hundred fossil shells of the country, which M. Deshayes finds to agree decidedly with the fossils of the Miocene period *.

The formation consists of different rocks, sand and sandstone, clay, coarse limestone, and a white oolite, the last of which is of great extent.

Montpellier.—The tertiary strata of Montpellier contain many of the Dax and Bordeaux species of shells, so that they are probably referrible to the Miocene epoch; but in the catalogue given by M. Marcel de Serres, many *Pliocene* species, similar to those of the Subapennine beds, are enumerated.

* Conch. Foss. du Plateau Wolhyni-Podo, par F. du Bois. Berlin, 1831.

This subject requires fuller investigation, and it would be highly interesting if the Montpellier beds should be found to indicate a passage from the fossils of the Miocene type to those of the older Pliocene. We are fully prepared for the discovery of such intermediate links, and we have endeavoured to provide a place for them in the classification proposed in the fifth chapter *.

* Page 57.

CHAPTER XVI.

Miocene alluviums—Auvergne—Mont Perrier—Extinct quadrupeds—Velay—Orleanais—Alluviums contemporaneous with Faluns of Touraine—Miocene fresh-water formations—Upper Val d'Arno—Extinct mammalia—Coal of Cadibona—Miocene volcanic rocks—Hungary—Transylvania—Styria—Auvergne—Velay.

In the present chapter we shall offer some observations on the alluviums and fresh-water formations of the Miocene era, and shall afterwards point out the countries in Europe where the volcanic rocks of the same period may be studied.

MIOCENE ALLUVIUMS.

Auvergne.—The annexed drawing will explain to the reader the position of two ancient beds of alluvium, *c* and *e*, in Au-

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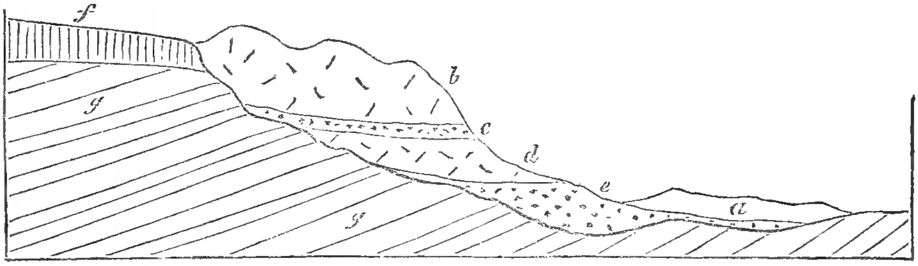

Position of the Miocene alluviums of Mont Perrier (or Boulade).

a, Newer alluvium.
b, Second trachytic breccia.
c, Second Miocene alluvium with bones.
d, First trachytic breccia.
e, First Miocene alluvium with bones.
f, Compact basalt.
g, Eocene lacustrine strata.

vergne, in which the remains of several quadrupeds characteristic of the Miocene period have been obtained. In order to account for the situation of these beds of rounded pebbles and sand, we must suppose that after the tertiary strata *g*, covered by the basaltic lava *f*, had been disturbed and exposed to aqueous denudation, a valley was excavated, wherein the alluvium *e* accumulated, and in which the remains of quadrupeds

then inhabiting the country were buried. The trachytic breccia *d* was then superimposed; this breccia is an aggregate of shapeless and angular fragments of trachyte, cemented by volcanic tuff and pumice, resembling some of the breccias which enter into the composition of the neighbouring extinct volcano of Mont Dor in Auvergne, or those which are found in Etna. Upon this rests another alluvium *c*, which also contains the bones of Miocene species, and this is covered by another enormous mass of tufaceous breccia. We suppose the breccias to have resulted from the sudden rush of large bodies of water down the sides of an elevated volcano at its moments of eruption, when snow perhaps was melted by lava. Such floods occur in Iceland, sweeping away loose blocks of lava and ejections surrounding the crater, and then strewing the plains with fragments of igneous rocks, enveloped in mud or 'moya.' The abrupt escarpment presented by the above-described beds, *b*, *c*, *d*, *e*, towards the valley of the Couze, must have been caused by subsequent erosion, whereby a large portion of those masses has been carried away *.

In the alluviums *c* and *e*, MM. Croizet, Jobert, Chabriol, and Bouillet have discovered the remains of about forty species of extinct mammalia, the greater part of which are peculiar as yet to this locality; but some of them characteristic of the Miocene period, being common to the faluns of Touraine, and associated in other localities with marine Miocene strata. Among these species may be enumerated Mastodon minor and M. arvernensis, Hippopotamus major, Rhinoceros leptorhinus and Tapir arvernensis. The Elephas primigenius, a species common to so many tertiary periods, is also stated to accompany the rest. In some cases the remains are not sufficiently characteristic to indicate the exact species, but the following genera can be determined: the boar, horse, ox, hyæna (two species), felis (three or four species), bear (three

* For an account of the position and age of the volcanic breccias of Mont Perrier and Boulade, see Lyell and Murchison on the beds of Mont Perrier, Ed. New Phil. Journ., July, 1829, p. 15.

species), deer, a great variety, canis, otter, beaver, hare, and water-rat *.

Velay.—In Velay a somewhat similar group of mammiferous remains were found by Dr. Hibbert †, in a bed of volcanic scoriæ and tuff, inclosed between two beds of basaltic lava, at Saint-Privat d'Allier. Some of the bones were found adhering to the slaggy lava. Among the animals were Rhinoceros leptorhinus, Hyæna spelæa, and another species allied to the spotted hyæna of the Cape, together with four undetermined species of deer ‡.

At Cussac and Solilhac, one league from Puy en Velay, M. Robert discovered, in an ancient alluvium covered with lava, the remains of Elephas primigenius, Rhinoceros leptorhinus, Tapir arvernensis, horse (two species), deer (seven species), ox (two species), and an antelope.

Orleanais.—In the Orleanais, at Avaray, Chevilly, les Aides, and les Barres, fossil land quadrupeds have been found associated with fluviatile shells and reptiles, identical with those found in the marine faluns of Touraine §. These are supposed, with great probability, by M. Desnoyers, to mark the passage of streams which flowed towards the sea in which the faluns were deposited. They bear the same relation to the Miocene strata of Touraine, as part of the ancient gravel and silt of England, containing the bones of elephants and other extinct animals, probably bear to the crag.

MIOCENE FRESH-WATER FORMATIONS.

Upper Val d'Arno.—There are a great number of isolated tertiary formations, of fresh-water origin, resting on primary and secondary rocks in different parts of Europe, in the same

* Recherches sur les Oss. Foss. du Dépt. du Puy de Dome, 4to., 1828.—Essai Geol. et Mineral. sur les Environs d'Issoire, Dépt. du Puy de Dome, folio, 1827.

† Edin. Journ. of Sci., No. 4, New Series, p. 276.

‡ Figures of some of these remains are given by M. Bertrand de Doue, Ann. de la Soc. d'Agricult. de Puy, 1828.

§ MM. Desnoyers and Lockart, Bulletin de la Soc. Géol., tom. ii. p. 336.

manner as we now find small lakes scattered over our continents and islands wherein deposits are forming, quite detached from all contemporary marine strata. To determine the age of such groups with reference to the great chronological series established for the marine strata, must often be a matter of difficulty, since we cannot always enjoy an opportunity of studying a locality where the fresh-water species are intermixed with marine shells, or where they occur in beds alternating with marine strata.

The deposit of the Upper Val d'Arno before alluded to, (p. 161) was evidently formed in an ancient lake; but although the fossil testaceous and mammiferous remains preserved therein are very numerous, it is scarcely possible, at present, to decide with certainty the precise era to which they belong. I collected six species of lacustrine shells, in an excellent state of preservation, from this basin belonging to the genera Anodon, Paludina and Neritina; but M. Deshayes was unable to identify them with any recent or fossil species known to him. If the beds belonged to the older Pliocene formations we might expect that several of the fossils would agree specifically with living testacea; and we are therefore disposed to believe that they belong to an older epoch. If we consider the terrestrial mammalia of the same beds, we immediately perceive that they cannot be assimilated to the Eocene type, as exhibited in the Paris basin, or in Auvergne and Velay: but some of them agree with Miocene species. Mr. Pentland has obligingly sent me the following list of the fossil mammifers of the Upper Val d'Arno which are in the museums of Paris.——*Feræ.*—Ursus cultridens, Viverra Valdarnensis, Canis lupus, and another of the size of the common fox. Hyæna radiata, H. fossilis. Felis (a new species of the size of the panther). *Rodentia.*—Histrix, nearly allied to dorsalis, Castor. *Pachydermata.*—Elephas Italicus, Mastodon angustidens, M. Taperoides, Tapir ——, Equus ——, Sus scrofa, Rhinoceros leptorhinus, Hippopotamus major, fossilis. *Ruminantia.*—

Cervus megaceros, (?) C. Valdarnensis, C. ——, new species, Bos, bubalo affinis, B. urus and B. taurus.

Cuvier also mentions the remains of a species of lophiodon as occurring among the bones in the Upper Val d'Arno *. The elephant of this locality has been called by Nesti † *meridionalis,* and is considered by him as distinct from the Siberian fossil species *E. primigenius,* with which, however, some eminent comparative anatomists regard it as identical. The skeletons of the hippopotamus are exceedingly abundant; no less than forty had been procured when I visited Florence in 1828. Remains of the elephant, stag, ox, and horse, are also extremely numerous. In winter the superficial degradation of the soil is so rapid, that bones which the year before were buried are seen to project from the surface of the soil, and are described by the peasants as growing. In this manner the tips of the horns of stags, or of the tusks of hippopotamuses often appear on the surface, and thus lead to the discovery of an entire head or skeleton.

Cadibona.—Another example of an isolated lacustrine deposit, belonging possibly to the Miocene period, is that which occurs at Cadibona, between Savona and Carcare. Its position is described in the annexed section, which does not however

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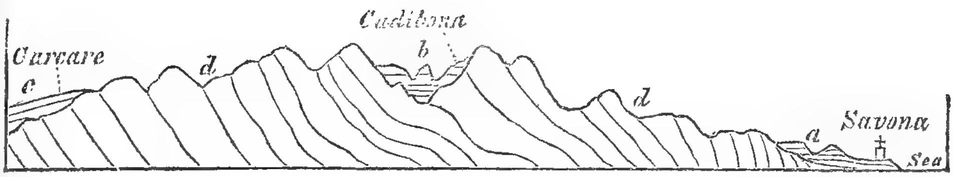

Section of the fresh-water formation of Cadibona.

a. Blue marl and yellow sand (older Pliocene).
b. Sand, shale and coal of Cadibona (Miocene?).
c. Green sand, &c. of the Bormida (Miocene).
d. Chloritic and micaceous schist, serpentine, &c.

pretend to accuracy in regard to the relative heights of the different rocks, or the distances of the places from each other.

* Oss. Foss., vol. v. p. 504.

† Lettere sopra alcune Ossa Fossili del Val d'Arno, &c. Pisa, 1825.

The lacustrine strata are composed of gravel, grit, and micaceous sandstone, of such materials as were derivable from the surrounding primary rocks; and so great is the thickness of this mass, that some valleys intersect it to the depth of seven or eight hundred feet without penetrating to the subjacent formations. In one part of the series, carbonaceous shales occur, and several seams of coal from two to six feet in thickness, but no impressions of plants of which the species could be determined, and no shells have been discovered. Many entire jaws and other bones of an extinct mammifer, called by Cuvier Anthracotherium, have been found in the coal-beds, the bone being itself changed into a kind of coal; but as this species does not occur elsewhere in association with organic remains of known date, it affords us no aid in our attempt to assign a place to the lignites of Cadibona *.

MIOCENE VOLCANIC ROCKS.

Hungary.—M. Beudant, in his elaborate work on Hungary, describes five distinct groups of volcanic rocks, which, although rarely of great extent, form striking features in the physical geography of that country, rising as they do abruptly from extensive plains composed of tertiary strata. They may have constituted islands in the ancient sea, as Santorin and Milo now do in the Grecian archipelago; and M. Beudant has remarked that the mineral products of the last-mentioned islands resemble remarkably those of the Hungarian extinct volcanos, where many of the same minerals, as opal, calcedony, resinous silex (*silex resinite*), pearlite, obsidian, and pitchstone abound.

The Hungarian lavas are chiefly felspathic, consisting of different varieties of trachyte; many are cellular and used as millstones; some so porous and even scoriform as to resemble those which have issued in the open air. Pumice occurs in great quantity, and there are conglomerates, or rather

* The author visited Cadibona in August, 1828, in company with Mr. Murchison.

breccias, wherein fragments of trachyte are bound together by pumiceous tuff or sometimes by silex.

It is probable that these rocks were permeated by the waters of hot springs, impregnated, like the Geysers, with silica; or, in some instances perhaps, by aqueous vapours, which, like those of Lancerote, may have precipitated hydrate of silica *.

By the influence of such springs or vapours the trunks and branches of trees washed down during floods, and buried in tuffs on the flanks of the mountains, may have become silicified. It is scarcely possible, says M. Beudant, to dig into any of the pumiceous deposits of these mountains without meeting with opalized wood, and sometimes entire silicified trunks of trees of great size and weight.

It appears from the species of shells collected principally by M. Boué, and examined by M. Deshayes, that the fossil remains imbedded in the volcanic tuffs, and in strata alternating with them in Hungary, are of the Miocene type, and no identical, as was formerly supposed, with the fossils of the Paris basin.

Transylvania.—The igneous rocks of the eastern part of Transylvania described by M. Boué, are probably of the same age. They cover a considerable area, and bear a close resemblance to the Hungarian lavas, being chiefly trachytic. Several large craters, containing shallow lakes like the Maars of the Eifel, are met with in some regions; and a rent in the trachytic mountains of Budoshagy exhales hot sulphureous vapours, which convert the trachyte into alum-stone, a change which that rock has undergone at remote periods in several parts of Hungary.

Styria.—Many of the volcanic groups of this country bear a similar relation to the Styrian tertiary deposits, as do the Hungarian rocks to the marine strata of that country. The shells are found imbedded in the volcanic tuffs in such a manner as to show that they lived in the sea when the volcanic eruptions were in progress, as many of the Val di Noto lavas

* See above, vol. i. chap. xxii.

in Sicily, before described, were shown to be contemporaneous with newer Pliocene strata *.

Auvergne—Velay.—We believe that part of the volcanic eruptions of Auvergne took place during the Miocene period; those, for example, which cover, or are interstratified with the alluviums mentioned in this chapter, and some of the ancient basaltic cappings of hills in Auvergne, which repose on gravel characterized by similar organic remains. A part also of the igneous rocks of Velay belong to this epoch, but to these we shall again refer when we treat more fully of the volcanic rocks of Central France; the older part of which are referrible to the Eocene period.

* Sedgwick and Murchison, Geol. Trans. Second Series, vol. iii. p. 400.—Daubeny, Extinct Volcanos, p. 92.

CHAPTER XVII.

Eocene period — Fresh-water formations — Central France — Map — Limagne d'Auvergne—Sandstone and conglomerate—Tertiary Red marl and sandstone like the secondary 'new red sandstone'—Green and white foliated marls—Indusial limestone—Gypseous marls—General arrangement and origin of the Travertin—Fresh-water formation of the Limagne—Puy en Velay—Analogy of the strata to those of Auvergne—Cantal—Resemblance of Aurillac limestone and its flints to our upper chalk—Proofs of the gradual deposition of marl—Concluding Remarks.

EOCENE FRESH-WATER FORMATIONS.

We have now traced back the history of the European formations to that period when the seas and lakes were inhabited by a few only of the existing species of testacea, a period which we have designated *Eocene*, as indicating the *dawn* of the present state of the animate creation. But although a small number only of the living species of animals were then in being, there are ample grounds for inferring that all the great classes of the animal kingdom, such as they now exist, were then fully represented. In regard to the testacea, indeed, it is no longer a matter of inference, for 1400 species of this class have been obtained from that small number of detached Eocene deposits which have hitherto been examined in Europe.

The celebrated Paris basin, the position of which was pointed out in the former part of this volume, (see wood-cut, p. 16) first presents itself, and seems to claim our chief attention when we treat of the phenomena of this era. But in order more easily to explain to the student the peculiar nature and origin of that group, it will be desirable, first, to give a brief sketch of certain deposits of Central France, which afford many interesting points of analogy, both in organic remains and mineral composition, and where the original circumstances under which the strata were accumulated may more easily be discerned.

Auvergne.—We allude to the lacustrine basins of Auvergne, Cantal, and Velay, the site of which may be seen in the

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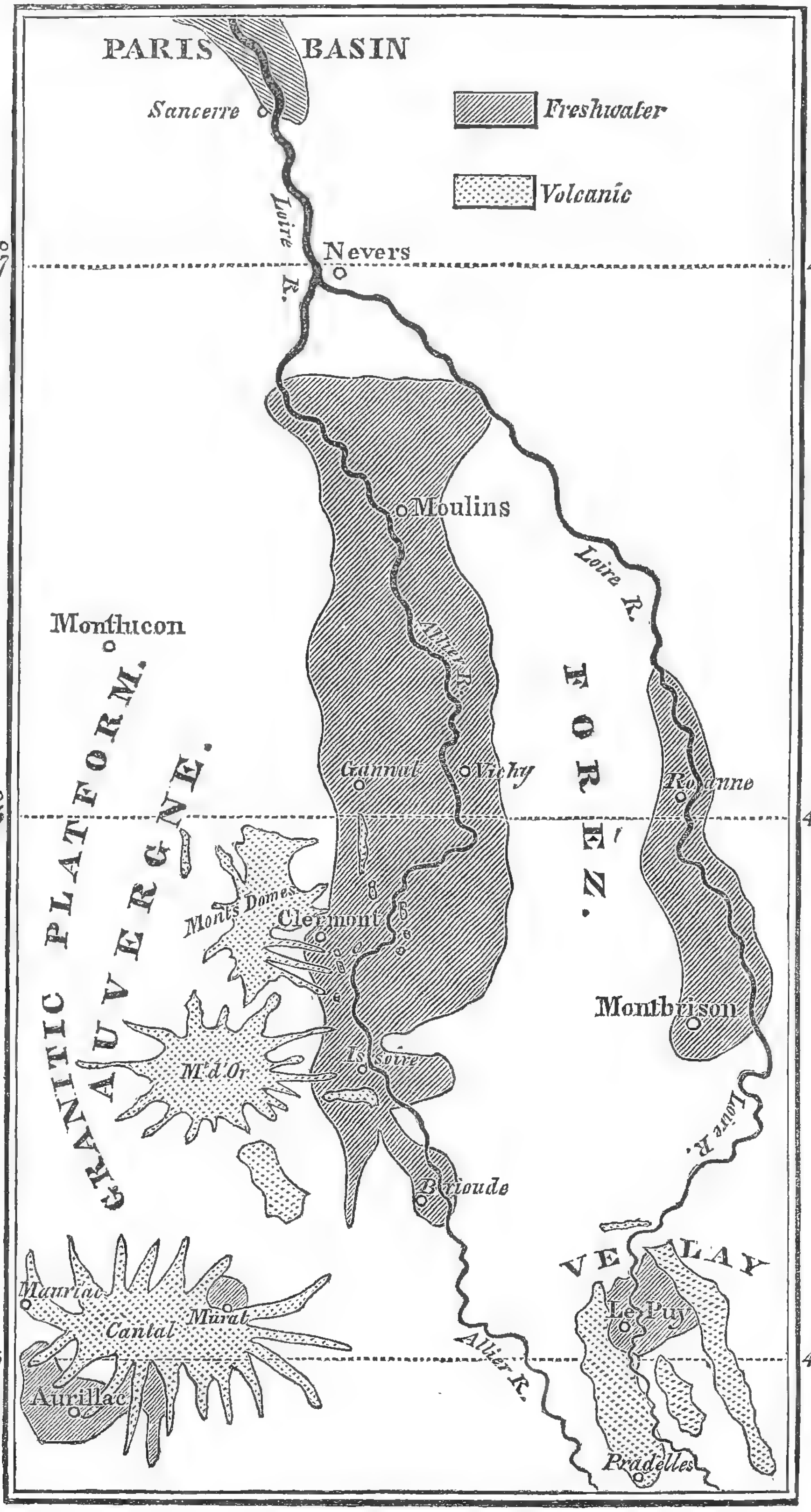

annexed Map *. They appear to be the monuments of ancient lakes which may have resembled in geographical distribution some of those now existing in Switzerland, and may like them have occupied the depressions in a mountainous country, and have been each fed by one or more rivers and torrents. The country where they occur is almost entirely composed of granite, and different varieties of granitic schist, with here and there a few patches of secondary strata much dislocated, and which have probably suffered great denudation. There are also some vast piles of volcanic rock, (see the Map,) the greater part of which are newer than the fresh-water strata, often resting upon them, whilst a small part were evidently of contemporaneous origin. Of these igneous rocks we shall treat more particularly in the nineteenth chapter, and shall first turn our attention exclusively to the lacustrine beds.

The most northern of the fresh-water groups is situated in the valley-plain of the Allier, which lies within the department of the Puy de Dome, being the tract which went formerly by the name of the Limagne d'Auvergne. It is inclosed by two parallel primitive ranges,—that of the Forèz, which divides the waters of the Loire and Allier, on the east, and that of the Monts Domes, which separates the latter river from the Sioule, on the west †. The average breadth of this tract is about 20 miles, and it is for the most part composed of nearly horizontal strata of sand, sandstone, calcareous marl, clay, limestone, and some subordinate groups, none of which observe a fixed and invariable order of superposition. The ancient borders of the lake, wherein the fresh-water strata were accumulated, may generally be traced with precision, the granite and other ancient rocks rising up boldly from the level country. The precise junction, however, of the lacustrine and granitic beds is rarely seen, as a small valley usually intervenes between them. The fresh-

* The following account of the fresh-water formations of Central France is the result of observations made in the summer of 1828, in company with Mr. Murchison.

† Scrope, Geology of Central France, p. 15.

water strata may sometimes be seen to retain their horizontality within a very slight distance of the border-rocks, while in some places they are inclined, and in a few instances vertical. The principal divisions into which the lacustrine series may be separated are the following: 1st, Sandstone, grit, and conglomerate. 2ndly, green and white foliated marls. 3dly, limestone or travertin, oolite, &c. 4thly, gypseous marls.

1. *Sandstone and conglomerate.*—Strata of sand and gravel, sometimes bound together into a solid rock, are found in great abundance around the confines of the lacustrine basin, containing, in different places, pebbles of all the ancient rocks of the adjoining elevated country, namely, granite, gneiss, mica-schist, clay-slate, porphyry, and others. But the arenaceous strata do not form one continuous band around the margin of the basin, being rather disposed like the independent deltas which grow at the mouths of torrents along the borders of existing lakes *.

At Chamalieres, near Clermont, we have an example of one of these littoral groups of local extent where the pebbly beds slope away from the granite as if they had formed a talus beneath the waters of the lake near the steep shore. A section, of about 50 feet in vertical height, has been laid open by a torrent, and the pebbles are seen to consist throughout of rounded and angular fragments of granite, quartz, primary slate, and red sandstone, but without any intermixture of those volcanic rocks which now abound in the neighbourhood. Partial layers of lignite and pieces of wood are found in these beds, but no shells, a fact which probably indicates that testacea could not live where the turbid waters of a stream were frequently hurrying down uprooted trees, together with sand and pebbles, or, that if they existed, they were triturated by the transported rocks.

There are other localities on the margin of the basin where quartzose grits are found, composed of white sand bound together by a siliceous cement.

* See vol. i. chap. xiv. p. 249; and 2nd. Ed. p. 286.

Occasionally, when the grits rest on granite, as at Chamalieres before mentioned, and many other places, the separate crystals of quartz, mica, and felspar, of the disintegrated granite, are bound together again by the silex, so that the granite seems regenerated in a new and even more solid form, and thus so gradual a passage may sometimes be traced between a crystalline rock and one of mechanical origin, that we can scarcely distinguish where one ends and the other begins.

In the Puy de Jussat, and the neighbouring hill of La Roche, are white quartzose grits, cemented into a sandstone by calcareous matter, which is sometimes so abundant as to form imbedded nodules. These sometimes constitute spheroidal concretions six feet in diameter, and pass into beds of solid limestone resembling the Italian travertins, or the deposits of mineral springs.

In the hills above mentioned, we have the advantage of seeing a section continuously exposed for about 700 feet in thickness. At the bottom are foliated marls, white and green, about 400 feet thick, and above, resting on the marls, are the quartzose grits before mentioned with the associated travertins. This section is observed close to the confines of the basin, so that the lake must here have been filled up near the shore with fine mud, before the coarse superincumbent sand was introduced. There are other cases where sand is seen below the marl.

2. *Red marl and sandstone.*—But the most remarkable of the arenaceous groups is a red sandstone and red marl, identical in all their characters with the secondary *new red sandstone* and marl of England. In the latter, the red ground is sometimes variegated with light greenish spots, and the same may be seen in its tertiary counterpart of fresh-water origin at Coudes, on the Allier. The marls are sometimes of a purplish-red colour, as at Champheix, and are accompanied by a reddish limestone, like the well-known 'cornstone,' which is associated with the old red sandstone of English geologists. The red sandstone and marl of Auvergne have evidently been derived from the

degradation of gneiss and mica-schist, which are seen *in situ* on the adjoining hills, decomposing into a soil very similar to the tertiary red sand and marl. We also find pebbles of gneiss, mica-schist, and quartz, in the coarser sandstones of this group, clearly pointing to the parent rocks from which the sand and marl were derived. The red beds, although destitute of organic remains, pass upwards into strata containing Eocene fossils, and are certainly an integral part of the lacustrine formation.

3. *Green and white foliated marls.*—A great portion of what we term clay in ordinary language, consists of the same materials as sandstone, but the component parts are in a finer state of subdivision. The same primary rocks, therefore, of Auvergne, which, by the partial degradation of their harder parts, gave rise to the quartzose grits and conglomerates before mentioned, would, by the reduction of the same into powder, and by the decomposition of their felspar, mica, and hornblende, produce aluminous clay, and, if a sufficient quantity of carbonate of lime was present, calcareous marl. This fine sediment would naturally be carried out to a greater distance from the shore, as are the various finer marls now deposited in Lake Superior *. And, as in the American lake, shingle and sand are annually amassed near the northern shores, so in Auvergne the grits and conglomerates before mentioned were evidently formed near the borders.

The entire thickness of these marls is unknown, but it certainly exceeds, in some places, 700 feet. They are for the most part either light-green or white, and usually calcareous. They are thinly foliated, a character which frequently arises from the innumerable thin plates or scales of that small animal called *cypris*, a genus which comprises several species, of which some are recent, and may be seen swimming rapidly through the waters of our stagnant pools and ditches. This animal resides within two small valves like those of a bivalve shell, and it moults its integuments annually, which the conchiferous

* See vol. i. chap. xiii.

molluscs do not. This circumstance may partly explain the countless myriads of the shells of cypris which were shed in the Eocene lakes, so as to give rise to divisions in the marl as thin as paper, and that too in stratified masses several hundred feet thick. A more convincing proof of the tranquillity and clearness of the waters, and of the slow and gradual process by which the lake was filled up with fine mud, cannot be desired. We may easily suppose that, while in the deep and central parts of the basin, this fine sediment was thrown down, gravel, sand, and rocky fragments were hurried into the lake near the shore, and formed the group first described.

Not far from Clermont the green marls, containing the cypris in abundance, approach to within a few yards of the granite which forms the borders of the basin. The annexed section occurs at Champradelle, in a small ravine north of La petite Baraque, and above the bridge.

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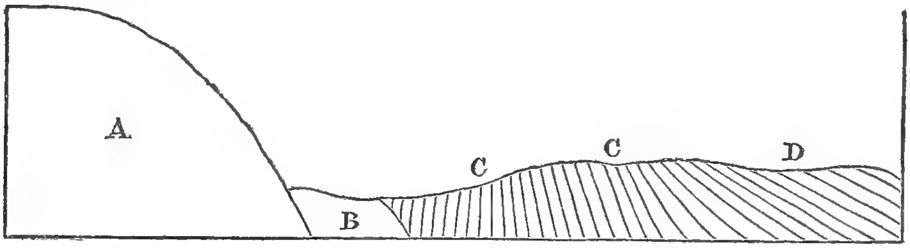


Vertical strata of marl near Clermont.

A, Granite. C, Green marl, vertical and inclined.
B, Space of 60 feet in which no section is seen. D. White marl.

The occurrence of these marls so near the ancient margin may be explained by considering that, at the bottom of the ancient lake in spaces intermediate between the points where rivers and torrents entered, no coarse ingredients were deposited, but finer mud only was drifted by currents. The *verticality* of some of the beds in the above section bears testimony to considerable local disturbance subsequent to the deposition of the marls, but such inclined and vertical strata are very rare.

4. *Limestone, travertin, &c.*—Both the preceding members of the lacustrine deposit, the marls and grits, pass occasionally

into limestone. Sometimes only concretionary nodules abound in them; but these, by an additional quantity of calcareous matter, unite, as already noticed (p. 229), into regular beds.

On each side of the basin of the Limagne, both on the east at Gannat, and on the west at Vichy, a white oolitic limestone is quarried. At Vichy, the oolite resembles our Bath stone in appearance and beauty, and, like it, is soft when first taken from the quarry, but soon hardens on exposure to the air. At Gannat, the stone contains land-shells and bones of quadrupeds, resembling those of the Paris gypsum. In several places in the neighbourhood of Gannat, at Marculot among others, this stone is divided by layers of clay.

At Chadrat, in the hill of La Serre, the limestone is pisolitic, and in this and other respects resembles the travertin of Tivoli. It presents the same combination, of a radiated and concentric structure, and the coats of the different segments of spheroids have the same undulating surface. (See wood-cut No. 5, chap. xii. vol. i.)

Indusial limestone.—There is another remarkable form of fresh-water limestone in Auvergne, called 'indusial,' from the cases, or *indusiæ*, of the larvæ of Phryganea, great heaps of which have been encrusted, as they lay, by hard travertin, and formed into a rock. We may often see, in our ponds, some of the living species of these insects, covered with small fresh-water shells, which they have the power of fixing to the outside of their tubular cases, in order, probably, to give them weight and strength. It appears that, in the same manner, a large species which swarmed in the Eocene lakes of Auvergne, was accustomed to attach to its dwelling the shells of a small spiral univalve of the genus *Paludina*. A hundred of these minute shells are sometimes seen arranged around one tube, part of the central cavity of which is still occasionally empty, the rest being filled up with thin concentric layers of travertin. When we consider that ten or twelve tubes are packed within the compass of a cubic inch, and that some single strata of this limestone are six feet thick, and may be

traced over a considerable area, we may form some idea of the countless number of insects and mollusca which contributed their integuments and shells to compose this singularly constructed rock. It is unnecessary to suppose that the Phryganeæ lived on the spots where their cases are now found; they may have multiplied in the shallows near the margin of the lake, and their buoyant cases may have been drifted by a current far into the deep water.

The calcareous strata of the Limagne, like the other members of the lacustrine formation, are for the most part horizontal, or inclined at a very slight angle, but instances of local dislocation are sometimes seen. At the town of Vichy, for example, the strata dip at an angle of between 30 and 40 degrees; in an ancient quarry behind the convent of Celestines, and near the hot spring at the same place, the beds of limestone are seen first inclined at an angle of 80°, and then vertical.

5. *Gypseous marls.*—More than 50 feet of thinly-laminated gypseous marls, exactly resembling those in the hill of Montmartre, at Paris, are worked for gypsum at St. Romain, on the right bank of the Allier. They rest on a series of green cypriferous marls which alternate with grits, the united thickness of this inferior group being seen, in a vertical section on the banks of the river, to exceed 250 feet.

General arrangement and origin of the fresh-water formations of Auvergne.—The relations of the different groups above described cannot be learnt by the study of any one section, and he who sets out with the expectation of finding a fixed order of succession may perhaps complain that the different parts of the basin give contradictory results. The arenaceous division, the marls and the limestone, may all be seen in some localities to alternate with each other, yet it can by no means be affirmed that there is no order of arrangement. The sands, sandstone, and conglomerate, constitute in general a littoral group; the foliated white and green marls a contemporaneous central deposit, and the limestone is for the most part subordinate to the newer portions of the above groups.

We never meet with calcareous rocks covered by a considerable thickness of quartzose sand or green marl, and the uppermost marls and sands are more calcareous than the lower. From the resemblance of the Eocene limestones of Auvergne to the Italian travertins, we may conclude that they were derived from the waters of mineral springs,—such springs as now exist in Auvergne, and which rising up through the granite precipitate travertin. They are sometimes thermal, but this character is by no means constant.

We suppose that, when the ancient lake of the Limagne first began to be filled with sediment, no volcanic action had produced lava and scoriæ on any part of the surface of Auvergne. No pebbles, therefore, of lava were transported into the lake,—no fragments of volcanic rocks imbedded in the conglomerate. But at a later period, when a considerable thickness of sandstone and marl had accumulated, eruptions broke out, and lava and tuff were alternately deposited, at some spots, with the lacustrine strata. Of this we shall give proofs in the 19th chapter. It is not improbable that cold and thermal springs, holding different mineral ingredients in solution, increased in number during the successive convulsions attending this development of volcanic agency, and thus carbonate and sulphate of lime, silex, and other minerals, were produced. Hence these minerals predominate in the uppermost strata. The subterranean movements may then have continued until they altered the relative levels of the country and caused the waters of the lakes to be drained off, and the farther accumulation of regular fresh-water strata to cease. The occurrence of these convulsions anterior to the Miocene epoch, and prolonged during a succession of after-ages, may explain why no fresh-water formations more recent than the Eocene are now found in this country.

We may easily conceive a similar series of events to give rise to analogous results in any modern basin, such as that of Lake Superior, for example, where numerous rivers and torrents are carrying down the detritus of a chain of mountains into the

lake. The transported materials must be arranged according to their size and weight, the coarser near the shore, the finer at a greater distance from land; but in the gravelly and sandy beds of Lake Superior no pebbles of modern volcanic rocks can be included, since there are none of these at present in the district. If the igneous action should break out in that country and produce lava, scoriæ, and thermal springs, the deposition of gravel, sand, and marl, might still continue as before; but in addition, there would then be an intermixture of volcanic gravel and tuff, and rocks precipitated from the waters of mineral springs.

Although the fresh-water strata of the Limagne approach generally to a horizontal position, the proofs of local disturbance are sufficiently numerous and violent to allow us to suppose great changes of level since the Eocene period. We are unable to assign a northern barrier to the ancient lake, although we can still trace its limits to the east, west, and south, where they were formed of bold granitic eminences. But we need not be surprised at our inability to restore the physical geography of the country after so great a series of volcanic eruptions. It is by no means improbable that one part of the district may have been moved upwards bodily, while the others remained at rest, or even suffered a movement of depression.

Puy en Velay.—In the department of the Haute Loire, a fresh-water formation, very analogous to that of Auvergne, is situated in the basin of the Loire, and is exposed in the valley in which stands the town of Le Puy. Since the deposition of the lacustrine strata, there have been so many volcanic eruptions in this country, and such immense quantities of lava and scoriæ poured out upon the surface, that the aqueous rocks are almost buried and concealed. We are indebted, however, to the researches of M. Bertrand de Doue for having distinctly ascertained the succession of strata, and we have had opportunities of verifying his observations during a visit to Le Puy.

In this basin we find, as in Auvergne, two great divisions, consisting of grits and marls; the former composed of quartzose

grit, sometimes granitiform, reddish and mottled sands and conglomerates, all evidently derived from the degradation of granitic rocks, and resembling exceedingly the arenaceous group of the Limagne before described. This formation is almost confined to the borders of the basin, and was evidently a littoral deposit. The other member of the formation, the *marls*, are more or less calcareous, and are associated with limestone and gypsum, which last is worked for agricultural uses, and exactly resembles that of Paris.

The analogy in the mineral character of the Velay and Paris basins is rendered more complete by the presence in both of silex in regular beds. In the limestone I found gyrogonites, or seeds of the Chara, of the same species as those most common in the Paris basin; and M. Bertrand de Doue has discovered the bones of several mammiferous animals of the same genera as those which characterize the basins of Auvergne and Paris *. The shells also of this formation correspond specifically with those of Eocene formations in other parts of France.

The sand and conglomerate of the fresh-water basin of Velay is entirely free from volcanic pebbles, agreeing in this respect with the analogous group of the Limagne; but the fact is the more striking in Velay, because the masses of trachyte, clinkstone, and other igneous rock now abounding in that country, have an aspect of extremely high antiquity, and constitute a most prominent feature in the geological structure of the district. Yet the non-intermixture of volcanic products with the lacustrine sediment, is just what we should expect when we have ascertained that the imbedded organic remains of those strata are Eocene; whereas the lavas belong in part, if not entirely, to the Miocene period †.

Cantal.—Near Aurillac, in Cantal, another series of fresh-water strata occurs, which resembles, in mineral character and organic remains, those of Auvergne and Velay already described. The leading feature of this group, as distinguished

* Descrip. Géognos. des Env. du Puy en Velay, 1823.

† See above, p. 219, and below, Chap. xix.

from the two former, is the immense abundance of silex associated with the calcareous marls and limestone, which last, like the limestone of Auvergne, constitutes an upper member of the fresh-water series.

The formation of the Cantal may be divided into two groups, the lowest composed of gravel, sand, and clay, such as might have been derived from the wearing down and decomposition of the granitic schists of the surrounding country; the upper system consisting of siliceous and calcareous marls, contains subordinately gypsum, silex, and limestone—deposits such as the waters of springs charged with carbonate and sulphate of lime, and with silica, may have produced.

Fresh-water limestone and flints resembling chalk.—To the English geologist, the most interesting feature in the Cantal is the resemblance of the fresh-water limestone, and its accompanying flint, to our upper chalk, a resemblance which, like that of the red sandstone of Auvergne to our secondary 'new red,' is the more important, as being calculated to put the student upon his guard against too implicit a reliance on lithological characters as tests of the relative ages of rocks. When we approach Aurillac from the west, we pass over great heathy plains, where the sterile mica-schist is barely covered with vegetation. Near Ytrac, and between La Capelle and Viscamp, we begin to see the surface strewed over with loose broken flints, some of them black in the interior, but with a white external coating, others stained with tints of yellow and red, and looking precisely like the flint gravel of our chalk districts. When heaps of this gravel have thus announced our approach to a new formation, we arrive at length at the escarpment of the lacustrine beds. At the bottom of the hill we see strata of clay and sand resting on mica-schist; and above, in the quarries of Belbet, Leybros, and Bruel, a white limestone, in horizontal strata, the surface of which has been hollowed out into irregular furrows, since filled up with broken flint, marl, and vegetable mould. We recognize in these cavities, filled with dark mould and flint gravel, an exact counterpart to

the appearances so frequently presented on the furrowed surface of our white chalk. Proceeding onwards from these quarries, along a road made of the white limestone, which reflects as glaring a light in the sun, as do our roads composed of chalk, we reach, at length, in the neighbourhood of Aurillac, hills of limestone and calcareous marl, in horizontal strata, separated in some places by regular layers of flint in nodules, the coating of each nodule being of an opaque white colour, like the exterior of the flinty nodules of our chalk. In these last the hard white substance has been ascertained to consist, in some instances, wholly of siliceous matter, and sometimes to contain a small admixture of carbonate of lime *, and the analysis of those of the Cantal would probably give the same results. The Aurillac flints have precisely the appearance of having separated from their matrix after the siliceous and calcareous matter had been blended together. The calcareous marl sometimes occupies small sinuous cavities in the flint, and the siliceous nodule, when detached, is often as irregular in form as those found in our chalk.

By what means, then, can the geologist at once decide that the limestone and silex of Aurillac are referrible to an epoch entirely distinct from that of the English chalk? It is not by reference to position, for we can merely say of the lacustrine beds, as we should have been able to declare of the true chalk had it been present, that they overlie the granitic rocks of this part of France. It is by reference to the organic remains that we are able to pronounce the formation to belong to the Eocene tertiary period. Instead of the marine Alcyonia of our cretaceous system, the silicified seed-vessels of the Chara, a plant which grows at the bottom of lakes, abound in the flints of Aurillac, both in those which are *in situ* and those forming the gravel. Instead of the Echinus and marine testacea of the chalk, we find in the marls and limestones the shells of the Planorbis, and other lacustrine testacea, all of

* Phillips, Geol. Trans. First Series, vol. v. p. 22.—Outlines of Geology, p. 95.

them, like the gyrogonites, agreeing specifically with species of the Eocene type.

Proofs of the gradual deposition of marl.—Some sections of the foliated marls in the valley of the Cer, near Aurillac, attest, in the most unequivocal manner, the extreme slowness with which the materials of the lacustrine series were amassed. In the hill of Barrat, for example, we find an assemblage of calcareous and siliceous marls, in which, for a depth of at least 60 feet, the layers are so thin that thirty are sometimes contained in the thickness of an inch; and when they are separated we see preserved in each the flattened stems of Charæ, or other plants, or sometimes myriads of small *paludinæ* and other freshwater shells. These minute foliations of the marl resemble precisely some of the recent laminated beds of the Scotch marl lakes, and when divided may be compared to the pages of a book, each containing a history of a certain period of the past. The different layers may be grouped together in beds from a foot to a foot and a half in thickness, which are distinguished by differences of composition and colour, the latter being white, green, and brown. Occasionally there is a parting layer of pure flint, or of black carbonaceous vegetable matter, one inch thick, or of white pulverulent marl. We find several hills in the neighbourhood of Aurillac composed of such materials for the height of more than 200 feet from their base, the whole sometimes covered by rocky currents of trachytic or basaltic lava *.

Concluding remarks.—So wonderfully minute are the separate parts of which some of the most massive geological monuments are made up! When we desire to classify, it is necessary to contemplate entire groups of strata in the aggregate; but if we wish to understand the mode of their formation, and to explain their origin, we must think only of the minute subdivisions of which each mass is composed. We must bear in mind how many thin, leaf-like seams of matter, each con-

* Lyell and Murchison, sur les Dépôts Lacust. Tertiaires du Cantal, &c. Ann. des Sci. Nat., Oct. 1829.

taining the remains of myriads of testacea and plants, frequently enter into the composition of a single stratum, and how great a succession of these strata unite to form a single group! We must remember, also, that volcanos like the Plomb du Cantal, which rises in the immediate neighbourhood of Aurillac, are equally the result of successive accumulation, consisting of reiterated flows of lava and showers of scoriæ; and we have shown, when we treated of the high antiquity of Etna, how many distinct lava-currents and heaps of ejected substances are required to make up one of the numerous conical envelopes whereof a volcano is composed.—Lastly, we must not forget that continents and mountain-chains, colossal as are their dimensions, are nothing more than an assemblage of many such igneous and aqueous groups, formed also in succession during an indefinite lapse of ages, and superimposed upon each other.

CHAPTER XVIII.

Marine formations of the Eocene period—Strata of the Paris basin how far analogous to the lacustrine deposits of Central France—Geographical connexion of the Limagne d'Auvergne and the Paris basin—Chain of lakes in the Eocene period—Classification of groups in the Paris basin—Observations of M. C. Prevost—Sketch of the different subdivisions of the Paris basin—Contemporaneous marine and fresh-water strata—Abundance of Cerithia in the Calcaire grossier—Upper marine formation indicates a subsidence—Part of the Calcaire grossier destroyed when the upper marine strata originated—All the Parisian groups belong to one great epoch—Microscopic shells—Bones of quadrupeds in gypsum—In what manner entombed—Number of species—All extinct—Strata with and without organic remains alternating—Our knowledge of the physical geography, fauna, and flora of the Eocene period considerable—Concluding remarks.

EOCENE FORMATIONS—PARIS BASIN.

THE geologist who has studied the lacustrine formations described in the last chapter cannot enter the tract usually termed 'the Paris Basin' without immediately recognizing a great variety of rocks with which his eye has already become familiar. The green and white marls of Auvergne, Cantal, and Velay, again present themselves, together with limestones and quartzose grits, siliceous and gypseous marls, nodules and layers of flint, and saccharoid gypsum; lastly, in addition to all this identity of mineral character, we find an assemblage of the same species of fossil animals and plants.

When we consider the geographical proximity of the two districts, we are the more prepared to ascribe this correspondence in the mineral composition of these groups to a combination of similar circumstances in the same era. From the map (No. 56, p. 226) in the last chapter, it will be seen that the united waters of the Allier and Loire, after descending from the valleys occupied by the fresh-water formations of Central France, flow on till they reach the southern extremity of what is called the Paris basin. M. Omalius d'Halloy long ago

suggested the very natural idea that there existed formerly a chain of lakes, reaching from the highest part of the central mountain-group of France, and terminating in the basin of Paris, which he supposes was at that time an arm of the sea.

Notwithstanding the great changes which the physical geography of that part of France must since have undergone, we may easily conceive that many of the principal features in the configuration of the country may have remained unchanged, or but slightly modified. Hills of volcanic matter have indeed been formed since the Eocene formations were accumulated, and the levels of large tracts have been altered in relation to the sea; lakes have been drained, and a gulf of the sea turned into dry land, but many of the reciprocal relations of the different parts of the surface may still remain the same. The waters which flowed from the granitic heights into the Eocene lakes may now descend in the same manner into valleys once the basins of those lakes. Let us, for example, suppose the great Canadian lakes, and the gulf into which their waters are discharged, to be elevated and laid dry by subterranean movements. The whole hydrographical basin of the St. Lawrence might be upraised during these convulsions, yet that river might continue, after so extraordinary a revolution, to drain the same elevated regions, and might continue to convey its waters in the same direction from the interior of the continent to the Atlantic. Instead of traversing the lakes, it would hold its course through deposits of lacustrine sand and shelly marl, such as we know to be now forming in Lakes Superior and Erie; and these fresh-water strata would occupy the site and bear testimony to the pristine existence of the lakes. Marine strata might also be brought into view in the space where an inlet of the sea, like the estuary of the St. Lawrence, had once received the continental waters; and in such formations we might discover shells of lacustrine and fluviatile species intermingled with marine testacea and zoophytes.

Subdivisions of strata in the Paris basin.—The area which has been called the Paris basin is about one hundred and

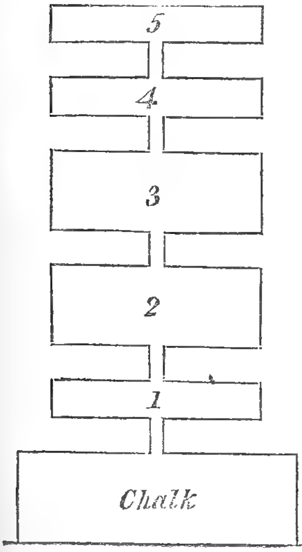
eighty miles in its greatest length from north-east to south-west, and about ninety miles from east to west. This space may be described as a depression in the chalk (see diagram No. 2, p. 16), which has been filled up by alternating groups of marine and fresh-water strata. MM. Cuvier and Brongniart attempted in 1811 to distinguish five different formations, and to arrange them in the following order, beginning with the lowest :—

1. First fresh-water formation....	Plastic clay. Lignite. First sandstone.
2. First marine formation	Calcaire grossier.
3. Second fresh-water formation ..	Siliceous limestone. Gypsum, with bones of animals. Fresh-water marls.
4. Second marine formation.......	Gypseous marine marls. Upper marine sands and sandstones. Upper marine marls and limestones.
5. Third fresh-water formation.	Siliceous millstone, without shells. Siliceous millstone, with shells. Upper fresh-water marls.

These formations were supposed to have been deposited in succession upon the chalk; and it was imagined that the waters of the ocean had been by turns admitted into and excluded from the same region. But the subsequent investigations of

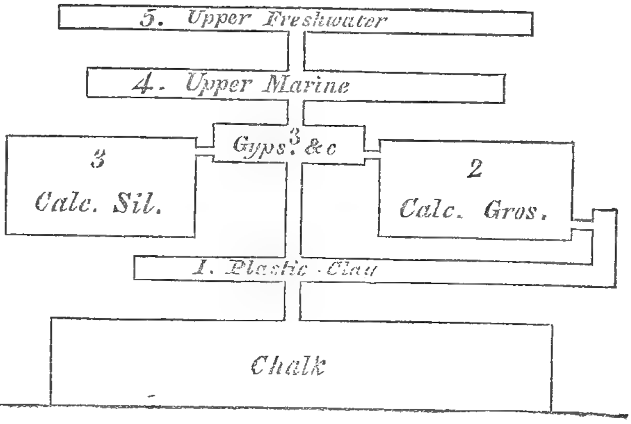
No. 58.

M. Alex. Brongniart.



No. 59.

M. Constant Prevost.



several geologists, especially of M. Constant Prevost *, have led to great modifications in the theoretical views entertained respecting the order in which the several groups were formed; and it now appears that the formations Nos. 1, 2, and 3, of the table of MM. Cuvier and Brongniart, instead of having originated one after the other, are divisible into four nearly contemporaneous groups.

Superposition of different formations in the Paris basin.—A comparison of the two accompanying diagrams will enable the reader to comprehend at a glance the different relations which the several sets of strata bear to each other, according to the original, as well as the more modern classification. We shall now proceed to lay before the reader a brief sketch of the several sets of strata referred to in the above systems.

Immediately upon the chalk a layer of broken chalk flints, often cemented into a breccia by siliceous sand, is very commonly found. These flints probably indicate the action of the sea upon reefs of chalk when a portion of that rock had emerged and before the regular tertiary beds were superimposed. To this partial layer no reference is made in the annexed sections.

Plastic clay and sand.—Upon this flinty stratum, or, if it be wanting, upon the chalk itself, rests frequently a deposit of clay and lignite (No. 1 of the above tables). It is composed of fresh-water shells and drift-wood, and was, at first, regarded as a proof that the Paris basin had originally been filled with fresh water. But it has since been shown that this group is not only of very partial extent, but is by no means restricted to a fixed place in the series; for it alternates with the marine calcaire grossier (No. 2 of the tables), and is repeated in the very middle of that limestone at Veaugirard, Bagneux, and other places, where the same Planorbes, Paludinæ, and Limnei occur †. M. Desnoyers pointed out to me a section in the suburbs of Paris, laid open in 1829, where a similar intercalation was seen in a still higher part of the calcaire grossier.

* Bulletin des Sci. de la Soc. Philom., May, 1825, p. 74.

† Prevost, Sur les Submersions Itératives, &c. Mem. de la Soc. d'Hist. Nat. de Paris, tome iv. p. 74.

These observations relieve us from the difficulty of seeking a cause why vegetable matter, and certain species of fresh-water shells and a particular kind of clay, was first introduced into the basin, and why the same space was subsequently usurped by the sea. A minute examination of the phenomena leads us simply to infer, that a river charged with argillaceous sediment entered a bay of the sea and drifted down, from time to time, fresh-water shells and wood.

Calcaire grossier.—The calcaire grossier above alluded to, is composed of a coarse limestone, often passing into sand, such as may perhaps have been derived from the aqueous degradation of a chalk country. It contains by far the greater number of the fossil shells which characterize the Paris basin. No less than 400 distinct species have been derived from a single locality near Grignon. They are imbedded in a calcareous sand, chiefly formed of comminuted shells, in which, nevertheless, individuals in a perfect state of preservation, both of marine, terrestrial, and fresh-water species, are mingled together, and were evidently transported from a distance. Some of the marine shells may have lived on the spot, but the Cyclostoma and Limnea must have been brought there by rivers and currents, and the quantity of triturated shells implies considerable movement in the waters.

Nothing is more remarkable in this assemblage of fossil testacea than the astonishing proportion of species referrible to the genus Cerithium *. There occur no less than 137 species of this genus in the Paris basin, and almost all of them in the calcaire grossier. Now the living testacea of this genus inhabit the sea near the mouths of rivers, where the waters are brackish, so that their abundance in the marine strata of the Paris basin is in perfect harmony with the hypothesis before advanced, that a river flowed into the gulf, and gave rise to the beds of clay and lignite before mentioned. But there are ample data for inferring that the gulf was supplied with fresh water by more than one river, for while the calcaire grossier occupies the northern

* See the tables of M. Deshayes, Appendix I., p. 26.

part of the Paris basin, another contemporaneous deposit, of fresh-water origin, appears at the southern extremity.

Calcaire siliceux.—This group (No. 3 of the foregoing tables) is a compact siliceous limestone, which resembles a precipitate from the waters of mineral springs. It is, for the most part, devoid of organic remains, but in some places it contains fresh-water and land species, and never any marine fossils. The siliceous limestone and the calcaire grossier occupy distinct parts of the basin, the one attaining its fullest development in those places where the other is of slight thickness. They also alternate with each other towards the centre of the basin, as at Sergy and Osny, and there are even points where the two rocks are so blended together, that portions of each may be seen in hand specimens. Thus in the same bed, at Triel, we have the compact fresh-water limestone, characterized by its Limnei, mingled with the coarse marine limestone through which the small multilocular shell, called milliolite, is dispersed in countless numbers. These microscopic testacea are also accompanied by Cerithia and other shells of the calcaire grossier. It is very extraordinary that, although in this instance both kinds of sediment must have been thrown down together on the same spot, each still contains its own peculiar organic remains*.

These facts lead irresistibly to the conclusion, that while to the north, where the bay was probably open to the sea, a marine limestone was formed, another deposit of fresh-water origin was introduced to the southward, or at the head of the bay. For it appears that during the Eocene period, as now, the ocean was to the north, and the continent, where the great lakes existed, to the south. From the latter region we may suppose a body of fresh water to have descended charged with carbonate of lime and silica, the water being perhaps in sufficient volume to convert the upper end of the bay into fresh water, like some of the gulfs of the Baltic.

Gypsum and marls.—The next group to be considered is

* M. Prevost has pointed out this limestone to me, both in situ at Triel, and in hand specimens in his cabinet.

the gypsum, and the white and green marls, subdivisions of No. 3 of the table of Cuvier and Brongniart. These were once supposed to be entirely subsequent in origin to the two groups already considered; but M. Prevost has pointed out that in some localities they alternate repeatedly with the calcaire siliceux, and in others with some of the upper members of the calcaire grossier. The gypsum, with its associated marls and limestone, is in greatest force towards the centre of the basin, where the two groups before mentioned are less fully developed; and M. Prevost infers, that while those two principal deposits were gradually in progress, the one towards the north, and the other towards the south, a river descending from the east may have brought down the gypseous and marly sediment.

It must be admitted, as highly probable, that a bay or narrow sea, 180 miles in length, would receive, at more points than one, the waters of the adjoining continent; at the same time we must observe, that if the gypsum and associated green and white marls of Montmartre were derived from an hydrographical basin distinct from that of the southern chain of lakes before adverted to, this basin must nevertheless have been placed under circumstances extremely similar; for the identity of the rocks of Velay and Auvergne with the fresh-water group of Montmartre, is such as can scarcely be appreciated by geologists who have not carefully examined the structure of both these countries.

Some of our readers may think that the view above given of the arrangement of four different sets of strata in the Paris basin is far more obscure and complicated than that first presented to them in the system of MM. Cuvier and Brongniart. We admit that the relations of the several sets of strata are less simple than the first observers supposed, being much more analogous to those exhibited by the lacustrine groups of Central France before described.

The simultaneous deposition of two or more groups of strata in one basin, some of them fresh-water and others marine, must

always produce very complex results; but in proportion as it is more difficult in these cases to discover any fixed order of superposition in the associated mineral masses, so also is it more easy to explain the manner of their origin and to reconcile their relations to the agency of known causes. Instead of the successive irruptions and retreats of the sea, and changes in the chemical nature of the fluid and other speculations of the earlier geologists, we are now simply called upon to imagine a gulf, into one extremity of which the sea entered, and at the other a large river, while other streams may have flowed in at different points, whereby an indefinite number of alternations of marine and fresh-water beds were occasioned.

Second or Upper marine group.—The next group, called the second or Upper marine formation (No. 4 of the tables), consists in its lower division of green marls which alternate with the fresh-water beds of gypsum and marl last described. Above this division the products of the sea exclusively predominate, the beds being chiefly formed of micaceous sand, 80 feet or more in thickness, surmounted by beds of sandstone with scarcely any limestone. The summits of a great many platforms and hills in the Paris basin consist of this upper marine series, but the group is much more limited in extent than the calcaire grossier. Although we fully agree with M. C. Prevost that the alternation of the various marine and fresh-water formations before described admit of a satisfactory explanation without supposing different retreats and subsequent returns of the sea, yet we think a subsidence of the soil may best account for the position of the upper marine sands. Oscillations of level may have occurred whereby for a time the sea and a river prevailed each in their turn, until at length a more considerable sinking down of part of the basin took place, whereby a tract previously occupied by fresh water was converted into a sea of moderate depth.

In one part of the Paris basin there are decisive proofs that during the Eocene period, and before the upper marine sand was formed, parts of the calcaire grossier were exposed to the

action of denuding causes. At Valmondois, for example, a deposit of the upper marine sandstone is found *, in which rolled blocks of the calcaire grossier with its peculiar fossils, and fragments of a limestone resembling the calcaire siliceux, occur. These calcareous blocks are rolled and pierced by perforating shells belonging to no less than fifteen distinct species, and they are imbedded, as well as worn shells washed out from the calcaire grossier, with the ordinary fossils of the upper marine sand.

We have seen that the same earthquake in Cutch could raise one part of the delta of the Indus and depress another, and cause the river to cut a passage through the upraised strata and carry down the materials removed from the new channel into the sea. All these changes, therefore, might happen within a short interval of time between the deposition of two sets of strata in the same delta †.

It is not improbable, then, that the same convulsions which caused one part of the Paris basin to sink down so as to let in the sea upon the area previously covered by gypsum and fresh-water marl, may have lifted up the calcaire grossier and the siliceous limestone, so that they might be acted upon by the waves, and fragments of them swept down into the contiguous sea, there to be drilled by boring testacea.

It is observed that the older marine formation at Laon is now raised 300 metres above the sea, whereas the upper marine sands never attain half that elevation. Such may possibly have been the relative altitude of the two groups when the newest of them was deposited.

Third fresh-water formation.—We have still to consider another formation, the third fresh-water group (No. 5 of the preceding tables). It consists of marls interstratified with beds of flint and layers of flinty nodules. One set of siliceous layers is destitute of organic remains, the other replete with them.

* M. Deshayes, Memoires de la Soc. d'Hist. Nat. de Paris, tom. i. p. 243.—The sandstone is called, by mistake, gres marin *inferieur*, instead of *superieur*, to which last the author has since ascertained it to belong.

† Vol. i. 2d Edit. chap. xxiii.; vol. ii. 1st Edit. chap. xvi.

Gyrogonites, or fossil seed-vessels of charæ, are found abundantly in these strata, and all the animal and vegetable remains agree well with the hypothesis, that after the gulf or estuary had been silted up with the sand of the upper marine formation, a great number of marshes and shallow lakes existed, like those which frequently overspread the newest parts of a delta. These lakes were fed by rivers or springs which contained, in chemical solution or mechanical suspension, such kinds of sediment as we have already seen to have been deposited in the lakes of Central France during the Eocene period.

The Parisian groups all Eocene.—Having now given a rapid sketch of the different groups of the Paris basin, we may observe generally that they all belong to the Eocene epoch, although the entire series must doubtless have required an immense lapse of ages for its accumulation. The shells of the different fresh-water groups, constituting at once some of the lowest and uppermost members of the series, are nearly all referrible to the same species, and the discordance between the marine testacea of the calcaire grossier and the upper marine sands is very inconsiderable.

A curious observation has been made by M. Deshayes, in reference to the changes which one species, the *Cardium porulosum,* has undergone during the long period of its existence in the Paris basin. Different varieties of this cardium are characteristic of different strata. In the oldest sand of the Soissonnais (a marine formation underlying the regular beds of the calcaire grossier), this shell acquires but a small volume, and has many peculiarities which disappear in the lowest beds of the calcaire grossier. In these the shell attains its full size, and many peculiarities of form, which are again modified in the uppermost beds of the calcaire grossier, and these last characters are preserved throughout the whole of the ‘upper marine’ series *.

Microscopic shells.—In some parts of the calcaire grossier microscopic shells are very abundant, and of distinct species

* Coquilles characterist. des Terrains, 1831.

from those before mentioned of the older Pliocene beds of Italy. We may remind those readers who are not familiar with these minute fossil bodies, that they belong to the order *Cephalopoda*, the animals of which are most free in their movements, and most advanced in their organization, of all the mollusca. The multilocular cephalopods have been separated, by d'Orbigny, into two subdivisions: first, those having a syphon or internal tube connecting the different chambers, such as the nautilus and ammonite; and, secondly, those without a syphon, to which the microscopic species now under consideration belong. They are often in an excellent state of preservation, and their forms are singularly different from those of the larger testacea. We have given a plate of some of these, from unpublished drawings by M. Deshayes, who has carefully selected the most remarkable types of form.

The *natural size* of each species figured in plate 4, is indicated by minute points, to which we call the reader's attention, as they might be easily overlooked.

Bones of quadrupeds in gypsum.—We have already considered the position of the gypsum which occurs in the form of a saccharoid rock in the hill of Montmartre at Paris, and other central parts of the basin. At the base of that hill it is seen distinctly to alternate with soft marly beds of the calcaire grossier, in which cerithia and other marine shells occur. But the great mass of gypsum may be considered as a purely fresh-water deposit, containing land and fluviatile shells, together with fragments of palm-wood, and great numbers of skeletons of quadrupeds and birds, an assemblage of organic remains which has given great celebrity to the Paris basin. The bones of fresh-water fish, also, and of crocodiles, and many land and fluviatile reptiles occur in this rock. The skeletons of mammalia are usually isolated, often entire, the most delicate extremities being preserved as if the carcasses clothed with their flesh and skin had been floated down soon after death, and while they were still swoln by the gases generated by their first decomposition. The few accompanying shells are of those light kinds

which frequently float on the surface of rivers together with wood.

M. Prevost has, therefore, suggested that a river may have swept away the bodies of animals, and the plants which lived on its borders, or in the lakes which it traversed, and may have carried them down into the centre of the gulf into which flowed the waters impregnated with sulphate of lime. We know that the Fiume Salso in Sicily enters the sea so charged with various salts that the thirsty cattle refuse to drink of it. A stream of sulphureous water, as white as milk, descends into the sea from the volcanic mountain of Idienne, on the east of Java; and a great body of hot water, charged with sulphuric acid, rushed down from the same on one occasion, and inundated a large tract of country, destroying, by its noxious properties, all the vegetation *. In like manner the Pusanibio, or 'Vinegar river' of Colombia, which rises at the foot of Puracé, an extinct volcano 7500 feet above the level of the sea, is strongly impregnated with sulphuric and muriatic acid, and with oxide of iron. We may easily suppose the waters of such streams to have properties noxious to marine animals, and in this manner we may explain the entire absence of marine remains in the ossifferous gypsum †.

There are no pebbles or coarse sand in the gypsum, a circumstance which agrees well with the hypothesis that these beds were precipitated from water holding sulphate of lime in solution, and floating the remains of different animals. The bones of land quadrupeds however are not confined entirely to the fresh-water formation to which the gypsum belongs, for the remains of a Palæotherium, together with some fresh-water shells have been found in a marine stratum belonging to the calcaire grossier at Beauchamp.

In the gypsum the remains of about fifty species of quadrupeds have been found all extinct and nearly four-fifths

* Leyde Magaz. voor Wetensch Konst en Lett., partie v. cahier i. p. 71. Cited by Rozet, Journ. de Geologie, tom. i. p. 43.

† M. C. Prevost, Submersions Itératives, &c. Note 23.

of them belonging to a division of the order Pachydermata, which is now only represented by four living species, namely by three tapirs and the daman of the Cape. A few carnivorous animals are associated, among which are a species of fox and gennet. Of the Rodentia, a dormouse and a squirrel; of the Insectivora, a bat; and of the Marsupialia, (an order now confined to America, Australia, and some contiguous islands,) an opossum, have been discovered.

Of birds about ten species have been ascertained, the skeletons of some of which are entire. None of them are referrible to existing species *. The same remark applies to the fish, according to MM. Cuvier and Agassiz, as also to the reptiles. Among the last are crocodiles and tortoises of the genera Emys and Trionix.

The tribe of land quadrupeds most abundant in this formation is such as now inhabits alluvial plains and marshes and the banks of rivers and lakes, a class most exposed to suffer by river inundations. Whether the disproportion of carnivorous animals can be ascribed to this cause, or whether they were comparatively small in number and dimensions, as in the indigenous fauna of Australia, when first known to Europeans, is a point on which it would be rash perhaps to offer an opinion in the present state of our knowledge.

We have no reason to be surprised that all the species of vertebrated animals hitherto observed are extinct, when we recollect that out of 1122 species of fossil testacea obtained from the Paris basin, 38 only can be identified with species now living. We have more than once adverted to the fact that extinct mammalia are often found associated with assemblages of *recent* shells, a fact from which we have inferred the inferior duration of species in mammalia as compared to the testacea; and it is not improbable that the higher order of animals in general may more readily become extinct than the marine molluscs. Some of the thirty-eight species of testacea above alluded to, as having survived from the Eocene period to our own times, have now a

* Cuvier, Oss. Foss. tom. iii. p. 255.

wide geographical range, as, for example, *Lucina divaricata*, and are therefore fitted to exist under a great variety of circumstances. On the other hand, the great proportion of the Eocene marine testacea which have become extinct sufficiently demonstrates that the loss of species has been due to general laws, and that a sudden catastrophe, such as the invasion of a whole continent by the sea—a cause which could only annihilate the terrestrial and fresh-water tribes, is an hypothesis wholly inadequate to account for the phenomenon.

Strata with and without organic remains alternating.—Between the gypsum of the Paris basin and the upper marine sands a thin bed of oysters is found, which is spread over a remarkably wide area. From the manner in which they lie, it is inferred that they did not grow on the spot, but that some current swept them away from a bed of oysters formed in some other part of the bay. The strata of sand which immediately repose on the oyster-bed are quite destitute of organic remains; and nothing is more common in the Paris basin and in other formations, than alternations of shelly beds with others entirely devoid of them. The temporary extinction and renewal of animal life at successive periods have been inferred from such phenomena, which may nevertheless be explained, as M. Prevost justly remarks, without appealing to any such extraordinary revolutions in the state of the animate creation. A current one day scoops out a channel in a bed of shelly sand and mud, and the next day, by a slight alteration of its course, ceases to prey upon the same bank. It may then become charged with sand unmixed with shells, derived from some dune, or brought down by a river. In the course of ages an indefinite number of transitions from shelly strata to those without shells may thus be caused.

Concluding remarks.—It will be seen by our observations on Auvergne and other parts of Central France, and on the district round Paris, that geologists have already gained a considerable insight into the state of the physical geography of part of Europe during the Eocene period. We can point to

some districts where lakes and rivers then existed, and to the site of some of the lands encircling those lakes, and to the position of a great bay of the sea, into which their surplus waters were discharged. We can also show, as we shall endeavour to explain in the next chapter, the points where some volcanic eruptions took place. We have acquired much information respecting the quadrupeds which inhabited the land at that period, and concerning the reptiles, fishes, and testacea which swarmed in the waters of lakes and rivers; and we have a collection of the marine Eocene shells more complete than has yet been obtained from any existing sea of equal extent in Europe. Nor are the contemporary fossil plants altogether unknown to us, which, like the animals, are of extinct species, and indicate a warmer climate than that now prevailing in the same latitudes.

When we reflect on the tranquil state of the earth implied by some of the lacustrine and marine deposits of this age, and consider the fullness of all the different classes of the animal kingdom, as deduced from the study of the fossil remains, we are naturally led to conclude, that the earth was at that period in a perfectly settled state, and already fitted for the habitation of man.

The heat of European latitudes during the Eocene period does not seem to have been superior if equal to that now experienced between the tropics; some *living* species of molluscous animals both of the land, the lake, and the sea, existed when the strata of the Paris basin were formed, and the contrast in the organization of the various tribes of Eocene animals when compared to those now co-existing with man, although striking, is not, perhaps, so great as between the living Australian and European types. At the same time we are fully aware that we cannot reason with any confidence on the capability of our own or any other contemporary species to exist under circumstances so different as those which might be caused by an entirely new distribution of land and sea; and we know that in the earlier tertiary periods the physical

geography of the northern hemisphere was very distinct. Our inability to account for the atmospheric and other latent causes, which often give rise to the most destructive epidemics, proves the extent of our ignorance of the entire assemblage of conditions requisite for the existence of any one species on the globe.

CHAPTER XIX.

Volcanic rocks of the Eocene period—Auvergne—Igneous formations associated with lacustrine strata—Hill of Gergovia—Eruptions in Central France at successive periods—Mont Dor an extinct volcano—Velay—Plomb du Cantal—Train of minor volcanos stretching from Auvergne to the Vivarais—Monts Domes—Puy de Côme—Puy Rouge—Ravines excavated through lava—Currents of lava at different heights—Subjacent alluviums of distinct ages—The more modern lavas of Central France may belong to the Miocene period—The integrity of the cones not inconsistent with this opinion—No eruptions during the historical era—Division of volcanos into ante-diluvian and post-diluvian inadmissible—Theories respecting the effects of the Flood considered—Hypothesis of a partial flood—Of a universal deluge—Theory of Dr. Buckland as controverted by Dr. Fleming—Recapitulation.

EOCENE VOLCANIC ROCKS.

When we treated in the seventeenth chapter of the lacustrine deposits of Central France, we purposely omitted to give a detailed account of the associated volcanic rocks, to which we now recall the attention of the reader. (See the Map, p. 226.)

We stated that, in the arenaceous and pebbly group of the lacustrine basins of Auvergne, Cantal, and Velay, no volcanic pebbles had ever been detected, although massive piles of igneous rocks are now found in the immediate vicinity. As this observation has been confirmed by minute research, we are warranted in inferring, as we before explained, that the volcanic eruptions had not commenced when the older subdivisions of the fresh-water groups originated.

In Cantal and Velay we believe no decisive proofs have yet been brought to light that any of the igneous out-bursts happened during the deposition of the fresh-water strata; but there can be no doubt that in Auvergne some volcanic explosions took place before the drainage of the lakes, and at a time when the Eocene species of animals and plants still flourished. We shall first advert to these proofs as relating to the history

of the period under consideration, and shall then proceed to show that there are in the same country volcanic rocks of much newer date, some of which appear to be referrible to the Miocene era.

Volcanic rocks associated with Lacustrine in Auvergne.—The first locality to which we shall call the reader's attention is Pont du Chateau near Clermont, where a section is seen in a precipice on the right bank of the river Allier *. Beds of volcanic tuff alternate with a fresh-water limestone, which is in some places pure, but in others spotted with fragments of volcanic matter, as if it were deposited while showers of sand and scoriæ were projected from a neighbouring vent †. This limestone contains the *Helix Ramondi* and other shells of Eocene species. It is immaterial to our present argument whether the volcanic sand was showered down from above, or drifted to the spot by a river, for the latter opinion must presuppose the country to have been covered with volcanic ejections during the Eocene period.

Another example occurs in the Puy de Marmont, near Veyres, where a fresh-water marl alternates with volcanic tuff containing Eocene shells. The tuff or breccia in this locality is precisely such as is known to result from volcanic ashes falling into water, and subsiding together with ejected fragments of marl and other stratified rocks. These tuffs and marls are highly inclined, and traversed by a thick vein of basalt which, as it rises in the hill, divides into two branches.

Gergovia.—The hill of Gergovia near Clermont affords a third example. We agree with MM. Dufrénoy and Jobert that there is no alternation here of lava and fresh-water strata, in the manner supposed by some other observers ‡; but the position and contents of some of the tuffs prove them to have been derived from volcanic eruptions which occurred during the deposition of the Eocene formations.

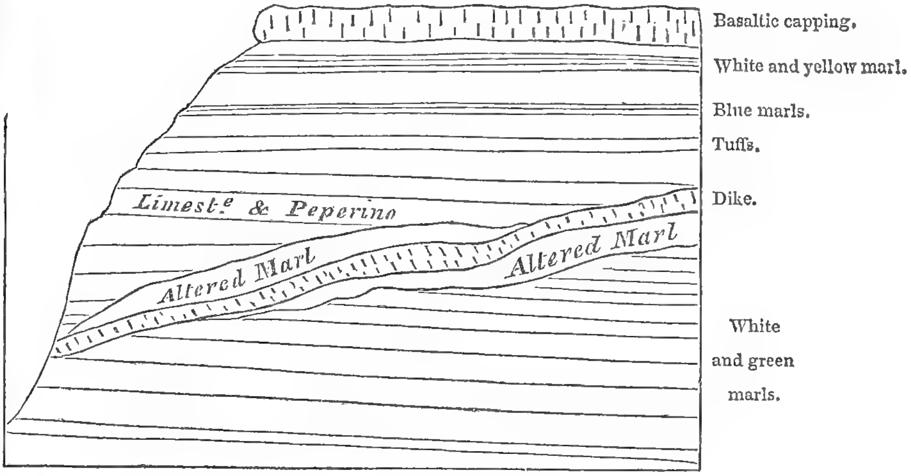
* This place, and all the others in Auvergne, mentioned in this chapter, were examined by the author, in company with Mr. Murchison, in 1828.

† See Scrope's Central France, p. 21.

‡ Scrope, ibid. p. 7.

The bottom of the hill consists of slightly inclined beds of white and greenish marls, more than three hundred feet in thickness, which are intersected by a dike of basalt, which may be studied in the ravine above the village of Merdogne. The dike here cuts through the marly strata at a considerable angle,

No. 60.



Hill of Gergovia.

producing, in general, great alteration and confusion in them for some distance from the point of contact. Above the white and green marls, a series of beds of limestone and marl, containing fresh-water shells, are seen to alternate with volcanic tuff. In the lowest part of this division, beds of pure marl alternate with compact fissile tuff resembling some of the subaqueous tuffs of Italy and Sicily called *peperinos.* Occasionally fragments of scoriæ are visible in this rock. Still higher is seen another group of some thickness, consisting exclusively of tuff, upon which lie other marly strata intermixed with volcanic matter.

There are many points in Auvergne where igneous rocks have been forced by subsequent injection through clays and marly limestones, in such a manner that the whole has become blended in one confused and brecciated mass, between which and the basalt there is sometimes no very distinct line of demarcation. In the cavities of such mixed rocks we often find calcedony and crystals of mesotype, stilbite and arragonite. To

formations of this class may belong some of the breccias immediately adjoining the dike in the hill of Gergovia; but it cannot be contended that the volcanic sand and scoriæ interstratified with the marls and limestones in the upper part of that hill were introduced, like the dike, subsequently by intrusion from below. They must have been thrown down like sediment from water, and can only have resulted from igneous action which was going on contemporaneously with the deposition of the lacustrine strata.

The reader will bear in mind that this conclusion agrees well with the proofs, adverted to in the seventeenth chapter, of the abundance of silex, travertin and gypsum precipitated when the upper lacustrine strata were formed: for these rocks, as we have pointed out, are such as the waters of mineral and thermal springs might generate.

The igneous products above mentioned, as associated with the lacustrine strata, form the lowest members of the great series of volcanic rocks of Auvergne, Cantal, and Velay, which repose for the most part on the granitic mountains (see Map, above, p. 226). There was evidently a long succession of eruptions, beginning with those of the Eocene period, and ending, so far as we can yet infer from the evidence derived from fossil remains, with those of the Miocene epoch. The oldest part of the two principal volcanic masses of Mont Dor and the Plomb du Cantal may perhaps belong to the Eocene period,—the newer portion of the same mountains to the Miocene; just as Etna commenced its operations during the newer Pliocene era, and has continued them down to the Recent epoch, and still retains its energy undiminished. There are some parts of the Mont Mezen, in Velay, which are perhaps of the same antiquity as the oldest parts of Mont Dor. Besides these ancient rocks, of which the lavas are in a great measure trachytic, there are many minor cones in Central France, for the most part of posterior origin, which extend from Auvergne, in a direction north-west and south-east, through Velay, into the Vivarais, where they are seen in the basin of

the Ardêche. This volcanic line does not pass by the Plomb du Cantal; it was formed, as nearly as we can conjecture in the present imperfect state of our knowledge, during the Miocene period; but there may probably be found, among these cones and their accompanying lavas, rocks of every intermediate age between the oldest and newest volcanic formations of Central France.

We shall first give a brief description of the Mont Dor and the Plomb du Cantal, and then pass on to the train of newer cones, examining the evidence at present obtained respecting their relative ages, and the light which they throw on the successive formation of alluviums and on the excavation of valleys.

Mont Dor.—Mont Dor, the most conspicuous of the volcanic masses of Auvergne, rests immediately on the granitic rocks standing apart from the fresh-water strata *. This volcano rises suddenly to the height of several thousand feet above the surrounding platform, and retains the shape of a flattened and somewhat irregular cone, all the sides sloping more or less rapidly, until their inclination is gradually lost in the high plain around. It is composed of layers of scoriæ, pumice-stones, and their fine detritus, interstratified with beds of trachyte and basalt, which descend often in uninterrupted currents, till they reach and spread themselves around the base of the mountain †. Conglomerates also, composed of angular and rounded fragments of igneous rocks, are observed to alternate with the above; and the various masses are seen to dip off from the central axis, and to lie parallel to the sloping flanks of the great cone, in the same manner as we have described when treating of Etna.

The summit of the mountain terminates in seven or eight rocky peaks, where no regular crater can be traced, but where we may easily imagine one to have existed which may have been shattered by earthquakes, and have suffered degradation by aqueous causes. Originally, perhaps, like the highest

* See the Map, p. 226. † Scrope's Central France, p. 98.

crater of Etna, it may have formed an insignificant feature in the great pile, and may frequently have been destroyed and renovated.

We cannot at present determine the age of the great mass of Mont Dor, because no organic remains have yet been found in the tuffs, except impressions of the leaves of trees of species not determined. Some of the lowest parts of the great mass are formed of white pumiceous tuffs, in which animal remains may perhaps be one day found. In the mean time, we conclude that Mont Dor had no existence when the grits and conglomerates of the Limagne, which contain no volcanic materials, were formed; but some of the earliest eruptions may perhaps have been contemporary with those described in the commencement of this chapter. To the latest of these eruptions, on the other hand, we refer those trachytic breccias of Mont Perrier which were shown in the sixteenth chapter, p. 217, to alternate with Miocene alluviums.

Velay.—The observations of M. Bertrand de Doue have not yet established that any of the most ancient volcanos of Velay were in action during the Eocene period, although it is very probable that some of them may have been contemporaneous with the oldest of the Auvergne lavas. There are beds of gravel in Velay, as in Auvergne, covered by lava at different heights above the channels of the existing rivers. In the highest and most ancient of these alluviums the pebbles are exclusively of granitic rocks; but in the newer, which are found at lower levels, they contain an intermixture of volcanic substances. We have already shown, in the sixteenth chapter, that, in the volcanic ejections and alluviums covered by the lavas of Velay, the bones of animals of Miocene species have been found, in which respect the phenomena accord perfectly with those of Auvergne.

Plomb du Cantal.—In regard to the age of the igneous rocks of the Cantal we are still less informed, and at present can merely affirm that they overlie the Eocene lacustrine strata of that country. The Plomb du Cantal (see Map, wood-cut

No. 56) is a conical mass, which has evidently been formed, like the cone of Etna, by a long series of eruptions. It is composed of trachytic and basaltic lavas, tuffs, and conglomerates, or breccias, forming a mountain several thousand feet in height. This volcano evidently broke out precisely on the site of the lacustrine deposit before described (Chapter xvii.), which had accumulated in a depression of a tract composed of micaceous schist. In the breccias, even to the very summit of the mountain, we find ejected masses of the fresh-water beds, and sometimes fragments of flint, containing Eocene shells. Deep valleys radiate in all directions from the central heights of the mountain, especially those of the Cer and Jourdanne, which are more than twenty miles in length, and lay open the geological structure of the mountain. No alternation of lavas with undisturbed Eocene strata have been observed, nor any tuffs containing fresh-water shells; on the northern side of the Plomb du Cantal, at La Vissiere, near Murat, we have pointed out on the Map (wood-cut, p. 226) a spot where fresh-water limestone and marl are seen covered by a thickness of about 800 feet of volcanic rock. Shifts are here seen in the strata of limestone and marl *.

Although it appears that the lavas of the Cantal are more recent than the fresh-water formation of that country, it does not follow that they may not belong to the Eocene period. The lake may possibly have been drained by the earthquakes which preceded or accompanied the first eruptions, but the Eocene animals and plants may have continued to exist for a long series of ages, while the cone went on increasing in dimensions.

Train of minor Volcanos.—We shall next consider those minor volcanos before alluded to, which stretch in a long range from Auvergne to the Vivarais, and which appear for the most part to be of newer origin than the mountains above described. They have been thrown up in a great number of isolated points, and much resemble those scattered over the

* See Lyell and Murchison, Ann. des Sci. Nat., Oct. 1829.

Phlegræan fields and the flanks of Etna. They have given rise chiefly to currents of basaltic lava, whereas those of Mont Dor and the Cantal are in great part trachytic. There are perhaps about three hundred of these minor cones in Central France; but a part of them only occur in Auvergne, where some few are found at the bottom of valleys excavated through the more ancient lavas of Mont Dor, as the Puy de Tartaret, for example, whence issues a current of lava which, flowing into the bed of the river Couze, gave rise to the lake of Chambon. Here the more ancient columnar basalts of Auvergne are seen forming the upper portion of the precipices which bound the valley.

But the greater part of the minor cones of Auvergne are placed upon the granitic platform, where they form an irregular ridge about eighteen miles in length and two in breadth. They are usually truncated at the summit, where the crater is often preserved entire, the lava having issued from the base of the hill. But frequently the crater is broken down on one side, where the lava has flowed out. The hills are composed of loose scoriæ, blocks of lava, lapilli, and puzzuolana, with fragments of trachyte and granite.

The lavas may be often traced from the crater to the nearest valley, where they usurp the channel of the river, which has often excavated a deep ravine through the basalt. We have thus an opportunity of contrasting the enormous degradation which the solid and massive rock has suffered by aqueous erosion and the integrity of the cone of sand and ashes which has, in the mean time, remained uninjured on the neighbouring platform, where it was placed beyond the reach of the power of running water.

Puy de Côme.—We may mention the Puy de Côme and its lava current, near Clermont, as one of the numerous illustrations of the phenomenon here alluded to. This conical hill rises from the granitic platform at an angle of about 40 degrees to the height of more than 900 feet. Its summit presents two distinct craters, one of them with a vertical depth of

250 feet. A stream of lava takes its rise at the western base of the hill, instead of issuing from either crater, and descends the granitic slope towards the present site of the town of Pont Gibaud. Thence it pours in a broad sheet down a steep declivity into the valley of the Sioule, filling the ancient river-channel for the distance of more than a mile. The Sioule, thus dispossessed of its bed, has worked out a fresh one between the lava and the granite of its western bank; and the excavation has disclosed, in one spot, a wall of columnar basalt about fifty feet high *.

The excavation of the ravine is still in progress, every winter some columns of basalt being undermined and carried down the channel of the river, and in the course of a few miles rolled to sand and pebbles. Meanwhile the cone of Côme remains stationary, its loose materials being protected by a dense vegetation, and the hill standing on a ridge not commanded by any higher ground whence floods of rain-water may descend.

Puy Rouge.—At another point, farther down the course of the Sioule, we find a second illustration of the same phenomenon in the Puy Rouge, a conical hill to the north of the village of Pranal. The cone is composed entirely of red and black scoriæ, tuff, and volcanic bombs. On its western side there is a worn-down crater whence a powerful stream of lava has issued and flowed into the valley of the Sioule. The river has since excavated a ravine through the lava and subjacent gneiss, to the depth of 400 feet.

On the upper part of the precipice forming the left side of this ravine, we see a great mass of black and red scoriaceous lava; below this a thin bed of gravel, evidently an ancient river-bed, now at an elevation of 50 feet above the channel of the Sioule. The gravel again rests upon gneiss, which has been eroded to the depth of 50 feet †. It is quite evident in this case that, while the basalt was gradually undermined and

* Scrope's Central France, p. 60, and plate.

† See Lyell and Murchison on the Excavation of Valleys, Edin. New Phil Journ., July 1829.

carried away by the force of running water, the cone whence the lava issued escaped destruction, because it stood upon a platform of gneiss several hundred feet above the level of the valley in which the force of running water was exerted.

It is needless to multiply examples, or the Vivarais would supply many others equally striking. Among many we may instance the cone of Jaujac, and its lava current *, which is a counterpart of that near Pranal last mentioned.

Lavas and Alluviums of different Ages.—We have seen that on the flanks of Etna, since the commencement of the present century, several currents of lava have flowed at the bottom of the Val del Bove, at the foot of precipices formed of more ancient lavas and tuffs. So we find in Auvergne that some streams of melted matter have flowed in valleys, the sides of which consist partly of older lavas. These are often seen capping the hills in broad sheets, resting sometimes on granite, sometimes on fresh-water strata.

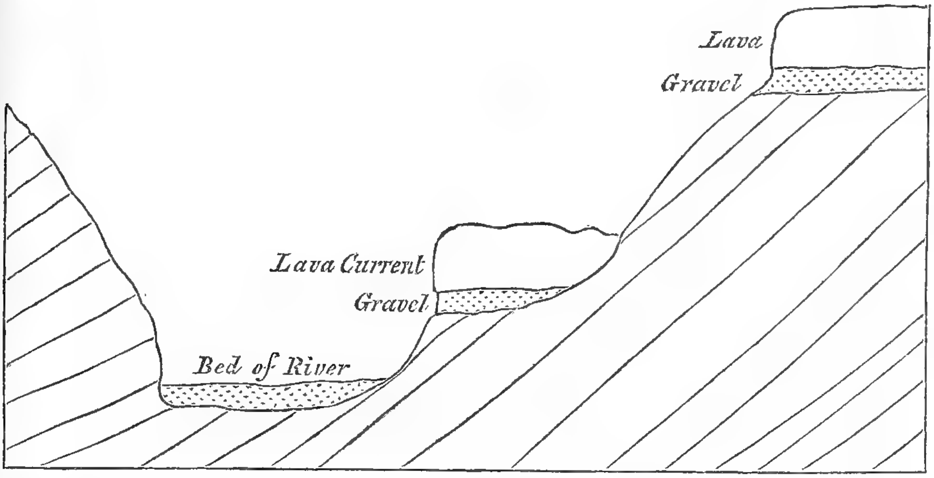
Many of the earlier lavas of Auvergne have flowed out upon the platform of granite before all the existing valleys had been excavated; others again spread themselves in broad sheets over the horizontal lacustrine deposit, when these had been covered with gravel, probably soon after the drainage of the lakes. Great vicissitudes in the physical geography of the country must have taken place since the flowing of these ancient lavas; and it is evident that the changes were gradual and successive, caused probably by the united agency of running water and subterranean movements. We frequently observe one mass of lava capping a hill, and a second at a lower elevation, forming a terrace on the side of a valley; or sometimes occupying the bed of a river.

It is a most interesting fact that we almost invariably find in these cases beds of gravel underlying the successive currents of lava, as in Catalonia before described (pp. 189, 190). Occasionally, when the highest platform of lava is 700 or 800 feet above the lowest, we cannot fail to be struck with the won-

* See Scrope's Central France, plate 14.

derful alterations effected in the drainage of the country since the first current flowed; for the most elevated alluviums must

No. 61.



Lavas of Auvergne resting on alluviums of different ages.

originally have been accumulated in the lowest levels of the then existing surface. As some geologists have referred almost all the superficial gravels to one era, and have supposed them to be the result of one sudden catastrophe, the phenomena of Auvergne above alluded to are very important. The flows of volcanic matter have preserved portions of the surface in the state in which they existed at successive periods, so that it is impossible to confound together the alluviums of different ages. The reader will see at once by reference to the wood-cut (No. 61) that a considerable interval of time occurred between the formation of the uppermost bed of gravel and that next below it; during which interval the uppermost lava was poured out and a valley excavated, at the bottom of which the second bed of gravel accumulated. In like manner the pouring out of a second current of lava, and a farther deepening of the valley, took place between the date of the second gravel and that of the modern alluvium which now fills the channel of the river *.

* For localities in Central France where lavas or sheets of basalt repose on alluviums at different elevations above the present valleys, consult the works of MM. Le Grand d'Aussi, Montlosier, Ramond, Scrope, Bertrand de Doue, Croizet, Jobert, Bouillet, and others.

When rivers are dispossessed of their channels by lava, they usually flow between the mass of lava and one side of the original valley. They then eat out a passage, partly through the volcanic and partly through the older formation; but as the soft tertiary marls in Auvergne give way more readily than the basalt, it is usually at the expense of the former that the enlarging and deepening of the new valley is effected, and all the remaining lava is then left on one side, in the manner represented in the above wood-cut.

Age of the more modern lavas.—The only organic remains found as yet in the ancient alluviums appear to belong to the Miocene period; but we have heard of none discovered in the gravel underlying the newest lavas,—those which either occupy the channels of the existing rivers or are very slightly elevated above them. We think it not improbable that even these may be of Miocene date, although the conjecture will appear extremely rash to some who are aware that the cones and craters whence the lavas issue, are often as fresh in their aspect as the majority of the cones of the forest zone of Etna.

The brim of the crater of the Puy de Pariou, near Clermont, is so sharp, and has been so little blunted by time, that it scarcely affords room to stand upon. This and other cones in an equally remarkable state of integrity have stood, we conceive, uninjured, not *in spite of* their loose porous nature, as some geologists might think, but in consequence of it. No rills can collect where all the rain is instantly absorbed by the sand and scoriæ, as we have shown to be the case on Etna (see above, p. 102), and nothing but a waterspout breaking directly upon the Puy de Pariou could carry away a portion of the hill, so long as it is not rent by earthquakes or engulphed.

Attempt to divide Volcanos into ante-diluvian and post-diluvian.—The opinions above expressed are entirely at variance with the doctrines of those writers who have endeavoured to arrange all the volcanic cones of Europe under two divisions,

those of ante-diluvian and those of post-diluvian origin. To the former they attribute such hills of sand and scoriæ as exhibit on their surface evident signs of aqueous denudation; to the latter, such as betray no marks of having been exposed to such aqueous action. According to this classification almost all the minor cones of Central France must be called post-diluvian; although, if we receive this term in its ordinary acceptation as denoting posteriority of date to the Noachian deluge, we are forced to suppose that all the volcanic eruptions occurred within a period of little more than twenty centuries, or between the era of the flood, which happened about 4000 years ago, and the earliest historical records handed down to us respecting the former state of Central France. Dr. Daubeny has justly observed, that had any of these French volcanos been in a state of activity in the age of Julius Cæsar, that general, who encamped upon the plains of Auvergne, and laid siege to its principal city, (Gergovia, near Clermont,) could hardly have failed to notice them. Had there been even any record of their existence in the time of Pliny or Sidonius Apollinaris, the one would scarcely have omitted to make mention of it in his Natural History, nor the other to introduce some allusion to it among the descriptions of this his native province. This poet's residence was on the borders of the Lake Aidat, which owed its very existence to the damming up of a river by one of the most modern lava currents*.

The ruins of several Roman bridges and of the Roman baths at Royat confirm the conclusion that no sensible alteration has taken place in the physical geography of the district, not even in the chasms excavated through the newest lavas since ages historically remote. We have no data at present for presuming that any one of the Auvergne cones has been produced within the last 4000 or 5000 years; and the

* Daubeny on Volcanos, p. 14.

same may be said of those of Velay. Until the bones of men or articles of human workmanship are found buried under some of their lavas, instead of the remains of extinct animals, which alone have hitherto been met with, we shall consider it probable, as we before hinted, that the latest of the volcanic eruptions may have occurred during the Miocene period.

Supposed effects of the Flood.

They who have used the terms ante-diluvian and post-diluvian in the manner above adverted to, proceed on the assumption that there are clear and unequivocal marks of the passage of a general flood over all parts of the surface of the globe. It had long been a question among the learned, even before the commencement of geological researches, whether the deluge of the Scriptures was universal in reference to the whole surface of the globe, or only so with respect to that portion of it which was then inhabited by man. If the latter interpretation be admissible, the reader will have seen, in former parts of this work, that there are two classes of phenomena in the configuration of the earth's surface, which might enable us to account for such an event. First, extensive lakes elevated above the level of the ocean; secondly, large tracts of dry land depressed below that level. When there is an immense lake, having its surface, like Lake Superior, raised 600 feet above the level of the sea, the waters may be suddenly let loose by the rending or sinking down of the barrier during earthquakes, and hereby a region as extensive as the valley of the Mississippi, inhabited by a population of several millions, might be deluged *. On the other hand, there may be a country placed beneath the mean level of the ocean, as we have shown to be the case with part of Asia †, and such a region must be entirely laid under water should the tract which separates it from the ocean

* See vol. i. p. 89, and Second Edition, p. 101.

† Vol. ii. p. 163, and Second Edition, p. 169.

be fissured or depressed to a certain depth. The great cavity of western Asia is 18,000 square leagues in area, and is occupied by a considerable population. The lowest parts, surrounding the Caspian Sea, are 300 feet below the level of the Euxine,—here, therefore, the diluvial waters might overflow the summits of hills rising 300 feet above the level of the plain; and if depressions still more profound existed at any former time in Asia, the tops of still loftier mountains may have been covered by a flood.

But it is undeniable, that the great majority of the older commentators have held the deluge, according to the brief account of the event given by Moses, to have consisted of a rise of waters over *the whole earth,* by which the summits of the loftiest mountains on the globe were submerged. Many have indulged in speculations concerning the instruments employed to bring about the grand cataclysm; and there has been a great division of opinion as to the effects which it might be expected to have produced on the surface of the earth. According to one school, of which De Luc in former times, and more recently Dr. Buckland, have been zealous and eloquent supporters, the passage of the flood worked a considerable alteration in the external configuration of our continents. By the last-mentioned writer the deluge is represented as a violent and transient rush of waters which tore up the soil to a great depth, excavated valleys, gave rise to immense beds of shingle, carried fragments of rock and gravel from one point to another, and, during its advance and retreat, strewed the valleys, and even the tops of many hills, with alluvium *.

But we agree with Dr. Fleming †, that in the narrative of Moses there are no terms employed that indicate the impetuous rushing of the waters, either as they rose or when they re-

* Buckland, Reliquiæ Diluvianæ.

† See a Memoir by the Rev. John Fleming, D. D., on the Geological Deluge, Edin. Phil. Journ., vol. xiv. p. 205, whose opinions were reviewed by the author in Oct. 1827, in an article in the Quarterly Review, No. lxxii. p. 481.

treated, upon the restraining of the rain and the passing of a wind over the earth. On the contrary, the olive-branch, brought back by the dove, seems as clear an indication to us that the vegetation was not destroyed, as it was then to Noah that the dry land was about to appear.

We have been led with great reluctance into this digression, in the hope of relieving the minds of some of our readers from groundless apprehension respecting the bearing of many of the views advocated in this work. They have been in the habit of regarding the diluvial theory above controverted as alone capable of affording an explanation of geological phenomena in accordance with Scripture, and they may have felt disapprobation at our attempt to prove, in a former chapter *, that the minor volcanos on the flanks of Etna may, some of them, be more than 10,000 years old. How, they would immediately ask, could they have escaped the denuding force of a diluvial rush of waters? The same objection may have presented itself when we quoted, with so much respect, the opinion of a distinguished botanist, that some living specimens of the Baobab tree of Africa, or the Taxodium of Mexico, may be five thousand years old †. Our readers may also have been astonished at the high antiquity assigned by us to the greater part of the European alluviums, and the many different ages to which we refer them ‡, as they may have been taught to consider the whole as the result of one *recent* and *simultaneous* inundation. Lastly, they may have felt some disappointment at observing, that we attach no value whatever to the hypothesis of M. Elie de Beaumont, adopted by Professor Sedgwick, that the sudden elevation of mountain-chains 'has been followed again and again by mighty waves desolating whole regions of the earth §,' a phenomenon which, according to the last-mentioned of these writers, has 'taken

* Chap. viii. p. 100. † See above, p. 99.
‡ P. 147. § P. 101.

away all anterior incredibility from the fact of a recent deluge*.'

For our own part, we have always considered the flood, if we are required to admit its universality in the strictest sense of the term, as a preternatural event far beyond the reach of philosophical inquiry, whether as to the secondary causes employed to produce it, or the effects most likely to result from it. At the same time, it is evident that they who are desirous of pointing out the coincidence of geological phenomena with the occurrence of such a general catastrophe, must neglect no one of the circumstances enumerated in the Mosaic history, least of all so remarkable a fact as that the olive remained standing while the waters were abating.

Recapitulation.—We shall now briefly recapitulate some of the principal conclusions to which we have been led by an examination of the volcanic districts of Central France.

1st. Some of the volcanic eruptions of Auvergne took place during the Eocene period, others at an era long subsequent, probably during the Miocene period.

2ndly. There are no proofs as yet discovered that the most recent of the volcanos of Auvergne and Velay are subsequent to the Miocene period, the integrity of many cones and craters not opposing any sound objection to the opinion that they may be of indefinite antiquity.

3rdly. There are alluviums in Auvergne of very different ages, some of them belonging to the Miocene period. Many of these have been covered by lava-currents which have been poured out in succession while the excavation of valleys was in progress.

4thly. There are a multitude of cones in Auvergne, Velay, and the Vivarais, which have never been subjected to the action of a violent rush of waters capable of modifying considerably the surface of the earth.

5thly. If, therefore, the Mosaic deluge be represented as universal, and as having exercised a violent denuding force, all

* Anniv. Address to the Geol. Soc., Feb. 18th, 1831.

these cones, several hundred in number, must be post-diluvian.

6thly. But since the beginning of the historical era, or the invasion of Gaul by Julius Cæsar, the volcanic action in Auvergne has been dormant, and there is nothing to countenance the idea that, between the date usually assigned to the Mosaic deluge and the earliest traditional and historical records of Central France (a period of little more than twenty centuries), all or any one of the more entire cones of loose scoriæ were thrown up.

Lastly, it is the opinion of some writers, that the earth's surface underwent no great modification at the era of the Mosaic deluge, and that the strictest interpretation of the scriptural narrative does not warrant us in expecting to find any geological monuments of the catastrophe, an opinion which is consistent with the preservation of the volcanic cones, however high their antiquity.

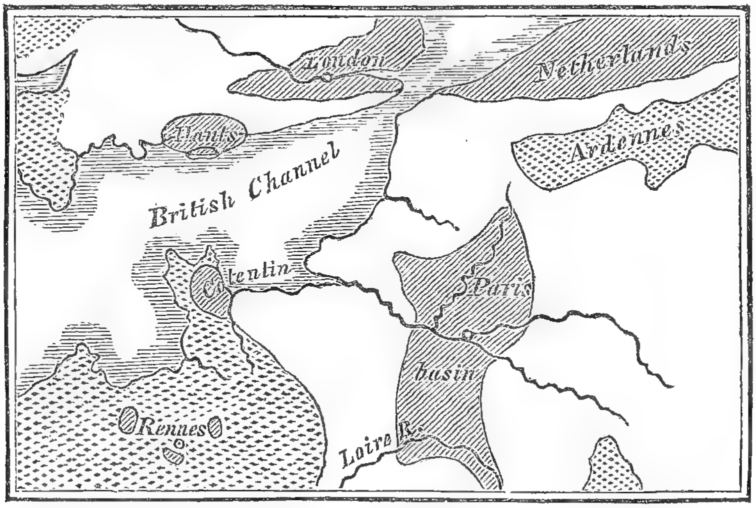
CHAPTER XX.

Eocene formations, *continued*—Basin of the Cotentin, or Valognes—Rennes—Basin of Belgium, or the Netherlands—Aix in Provence—Fossil insects—Tertiary strata of England—Basins of London and Hampshire—Different groups—Plastic clay and sand—London clay—Bagshot sand—Fresh-water strata of the Isle of Wight—Palæotherium and other fossil mammalia of Binstead—English Eocene strata conformable to chalk—Outliers on the elevated parts of the chalk—Inferences drawn from their occurrence—Sketch of a theory of the origin of the English tertiary strata.

Having in the last three chapters treated of the Eocene formations of different parts of France, we now propose to examine those which are found in the south-eastern division of England; but before we pass from the continent to our own island, we may briefly advert to several other spots where Eocene deposits have been observed. Their geographical position will be found delineated on the annexed map*.

MAP OF THE PRINCIPAL TERTIARY BASINS OF THE EOCENE PERIOD.

No. 62.



Primary rocks and strata older than the carboniferous series. Eocene formations.

N.B. The space left blank is occupied by secondary formations, from the old red sandstone to the chalk inclusive.

* This map is copied from one given by M. Desnoyers, Mem. de la Soc. d'Hist. Nat. de Paris, 1825, pl. 9; compiled partly from that author's observations, and partly from Mr. Webster's map, Geol. Trans., 1st series, vol. ii. plate 10.

Basin of the Cotentin, or Valognes.—The strata in the environs of Valognes, in the department of La Manche, consist chiefly of a coarse limestone resembling the calcaire grossier of Paris, of which M. Desnoyers has given an elaborate description. It is occasionally covered with a compact fresh-water limestone alternating with fresh-water marls. In these Eocene strata more than 300 species of fossil shells have been discovered, almost all identical with species of the Paris basin. (See Tables, Appendix I.) Superimposed upon the Eocene strata of this basin is a newer marine deposit, extending over a limited area, the fossils of which agree with those of the Faluns of the Loire*. Here, therefore, the geologist has an opportunity of observing the superposition of the Miocene deposits upon those of the age of the Paris basin.

Rennes.—Several small patches, also, of marine strata, have been found by M. Desnoyers, in the neighbourhood of Rennes, which are characterised by Eocene fossils and repose on ancient rocks, as will be seen in the map.

Basin of Belgium, or the Netherlands.—The greater part of the tertiary formations of the Low Countries consist of clay and sand, much resembling those of the basin of London, afterwards to be described. The fossil shells, also, are of the same species, 49 of which will be found referred to by M. Deshayes, in the tables, Appendix I.

Aix, in Provence.—The tertiary strata of Aix and Fuveau in Provence are of great thickness and extent, the lower members being remarkable for containing coal grit and beds of compact limestone, such as we only find in England in ancient secondary groups. Yet these strata are for the most part of fresh-water origin, and contain several species of Eocene shells, together with many which are peculiar to this basin. It would require a fuller comparison than has yet been made of the fossil remains of Aix and Fuveau, before we can determine with accuracy the relative age of that formation. Some of the plants seem to agree with those of the Paris basin, while many

* Desnoyers, Mem. de la Soc. d'Hist. Nat. de Paris, 1825.

of the insects have been supposed identical with species now living*. These insects have been almost exclusively procured from a thin bed of grey calcareous marl, which passes into an argillaceous limestone found in the quarries of gypsum near Aix. The rock in which they are imbedded is so thinly laminated that there are sometimes more than 70 layers in the thickness of an inch. The insects are for the most part in an extraordinary state of preservation, and an impression of their form is seen both on the upper and under laminæ, as in the case of the Monte Bolca fishes. M. Marcel de Serres enumerates 62 genera belonging chiefly to the orders Diptera, Hemiptera and Coleoptera. On reviewing a collection brought from Aix, Mr. Curtis observes that they are all of European forms and most of them referrible to existing genera †. With the single exception of an Hydrobius, none of the species are aquatic. The antennæ, tarsi, and trophi are generally very obscure, or distorted, yet in a few the claws are visible, and the sculpture, and even some degree of local colouring, are preserved. The nerves of the wings, in almost all the Diptera, are perfectly distinct, and even the pubescence on the head of one of them. Several of the beetles have the wings extended beyond the elytra, as if they had made an effort to escape by flying, or had fallen into the water while on the wing ‡.

BASINS OF LONDON AND HAMPSHIRE.

The reader will see in the small map above given (No. 62, p. 275,) the position of the two districts usually called the basins of London and Hampshire, to which the Eocene formations of England are confined. These tracts are bounded by rising grounds composed of chalk, except where the sea intervenes. That the chalk passes beneath the tertiary strata, we can not only infer from geological data, but can prove by numerous artificial sections at points where wells have been sunk, or borings made through the overlying beds. The

* M. Marcel de Serres, Géog. des Ter. Tertiaires du Midi de la France.

† Murchison and Lyell. Ed. New Phil. Journ., Oct. 1829.

‡ Curtis, ibid., where figures of some of the insects are given.

Eocene deposits are chiefly marine, and have generally been divided into three groups: 1st, the Plastic clay and sand, which is the lowest group; 2dly, the London clay; and, 3rdly, the Bagshot sand. Of all these the mineral composition is very simple, for they consist almost entirely of clay, sand, and shingle, the great mass of clay being in the middle, and the upper and lower members of the series being more arenaceous.

Plastic clay and sand.—The lowest formation, which sometimes attains a thickness of from 400 to 500 feet, consists principally of an indefinite number of beds of sand, shingle, clay, and loam, irregularly alternating, some of the clay being used in potteries, in reference to which the name of Plastic clay has been given to the whole formation. The beds of shingle are composed of perfectly rolled chalk flints, with here and there small pebbles of quartz. Heaps of these materials appear sometimes to have remained for a long time covered by a tranquil sea. Dr. Buckland mentions that he observed a large pebble in part of this formation at Bromley, to which five full-grown oyster-shells were affixed, in such a manner as to show that they had commenced their first growth upon it, and remained attached through life *.

In some of the associated clays and sand, perfect marine shells are met with, which are of the same species as those of the London clay. The line of separation, indeed, between the superincumbent blue clay last alluded to, and the Plastic clay and sand, is quite arbitrary, as any geologist may be convinced who examines the celebrated section in Alum Bay, in the Isle of Wight †, where a distinct alternation of the two groups is observable, each marked with their most characteristic peculiarities. In the midst of the sands of the lower series a mass of clay occurs 200 feet thick, containing septaria, and replete with the usual fossils of the neighbourhood of London ‡.

* Geol. Trans., First Series, vol. iv. p. 300.

† See Mr. Webster's Memoir, Geol. Trans., vol. ii., First Series, and his Letters in Sir H. Englefield's Isle of Wight.

‡ See Mr. Webster's sections, plate 11. Geol. Trans., vol. ii., First Series.

The *arenaceous* beds are chiefly laid open on the confines of the basins of London and Hampshire, in following which we discover at many places great beds of perfectly rounded flints. Of this description, on the southern borders of the basin of London, are the hills of Comb Hurst and the Addington hills, which form a ridge stretching from Blackheath to Croydon. Here they have much the appearance of banks of sand and shingle formed near the shores of the tertiary sea; but whether they were really of littoral origin cannot be determined for want of a sufficient number of sections which might enable us to compare the tertiary strata at the edges with those in the central parts of each basin.

We have ample opportunities in the basin of Paris of examining steep cliffs of hard rock which bound many of the valleys, and innumerable excavations have been made for building-stone, limestone, and gypsum; but when we attempt to obtain a connected view of any considerable part of the tertiary series in the basin of London, we are almost entirely limited to a single line of coast-section; for in the interior the regular beds are much concealed by an alluvial covering of flint gravel spread alike over the summits and gentle slopes of the hills, and over the bottoms of the valleys.

Organic remains are extremely scarce in the Plastic clay; but when any shells occur they are of Eocene species. Vegetable impressions and fossil wood sometimes occur, and even beds of lignite, but none of the *species* of plants have, we believe, as yet been ascertained.

London clay.—This formation consists of a bluish or blackish clay, sometimes passing into a calcareous marl, rarely into a solid rock. Its thickness is very great, sometimes exceeding 500 feet *. It contains many layers of ovate or flattish masses of argillaceous limestone, which, in their interior, are generally traversed in various directions by cracks, partially or wholly filled by calcareous spar. These masses, called septaria, are sometimes continued through a thickness of 200 feet †.

* Con. and Phil. Outlines of Geol., p. 33.

† Outlines of Geol., p. 27.

A great number of the marine shells of this clay have been identified with those of the Paris basin, and are mentioned by name in Appendix I. It is quite evident, therefore, that these two formations belong to the same epoch.

No remains of terrestrial mammalia have as yet been found in this clay, but the occurrence of bones and skeletons of crocodiles and turtles prove, as Mr. Conybeare justly remarks, the existence of neighbouring dry land. The shores, at least, of some islands were accessible, whither these creatures may have resorted to lay their eggs. In like manner, we may infer the contiguity of land from the immense number of ligneous seed-vessels of plants, some of them resembling the cocoa-nut, and other spices of tropical regions, which have been found fossil in great profusion in the Isle of Sheppey. Such is the abundance of these fruits, that they have been supposed to belong to several hundred distinct species of plants.

Bagshot sand.—The third and uppermost group, usually termed the Bagshot sand, rests conformably upon the London clay, and consists of siliceous sand and sandstone devoid of organic remains, with some thin deposits of marl associated. From these *marls* a few marine shells have been obtained which are in an imperfect state, but appear to belong to Eocene species common to the Paris basin *.

Fresh-water strata of the Hampshire basin.—In the northern part of the Isle of Wight, and part of the opposite coast of Hampshire, fresh-water strata occur resting on the London clay. They are composed chiefly of calcareous and argillaceous marls, interstratified with some thick beds of siliceous sand, and a few layers of limestone sometimes slightly siliceous. The marls are often green, and bear a considerable resemblance to the green marls of Auvergne and the Paris basin. The shells and gyrogonites also agree specifically with some of those most common in the French deposits. Mr. Webster, who first described the fresh-water formation of Hampshire, divided it into an upper and lower series separated by intervening beds of marine

* Warburton, Geol. Trans., vol. i. Second Series.

origin. There are undoubtedly certain intercalated strata, both in the Isle of Wight and coast of Hampshire, marked by a slight intermixture of marine and fresh-water shells, sufficient to imply a temporary return of the sea, before and after which the waters of a lake, or rather, perhaps, some large river, prevailed *. The united thickness of the fresh-water and intercalated upper marine beds, exposed in a vertical precipice in Headen Hill, in the Isle of Wight, is about 400 feet, the marine series appearing about half way up in the cliff.

Eocene mammiferous remains.—Very perfect remains of tortoises and the teeth of crocodiles have been procured from the fresh-water strata, but a still more interesting discovery has recently been made. The bones of mammalia corresponding to those of the celebrated gypsum of Paris, have been disinterred at Binstead, near Ryde, in the Isle of Wight. In the ancient quarries near this town a limestone, belonging to the lower fresh-water formation, is worked for building. Solid beds alternate with marls, wherein a tooth of an Anoplotherium, and two teeth of the genus Palæotherium, were found. These remains were accompanied not only by several other fragments of the bones of Pachydermata (chiefly in a rolled and injured state), but also by the jaw of a new species of Ruminantia, apparently closely allied to the genus Moschus †. Mr. T. Allan of Edinburgh had several years before found the tooth of an Anoplotherium at the same spot, and when we alluded to this in our first volume ‡, we threw out some doubts as to the authenticity of his specimen, stating at the same time, that in the Binstead beds, if anywhere in our island, we should expect such remains to be found. Although we carried our scepticism too far, it has been attended with good results, for it induced Mr. Pratt to visit Binstead, where he verified and extended the discovery of Mr. Allan.

* See Memoirs of Mr. Webster, Geol. Trans., vol. ii., First Series, vol. i. part i., Second Series, and Englefield's Isle of Wight.—Professor Sedgwick, Ann. of Phil., 1822, and Lyell, Geol. Trans., vol. ii. Second Series.

† Pratt, Proceedings of Geol. Soc., No. 18, p. 239.

‡ First Edition, p. 153.

These newer strata of the Isle of Wight bear a certain degree of resemblance to some of the green marls and limestones in the Paris basin, yet, as a whole, no formations can be more dissimilar in mineral character than the Eocene deposits of England and Paris. In our own island the tertiary strata are more exclusively marine, and it might be said that the Parisian series differs chiefly from that of London in the very points in which it agrees with the formations of Auvergne, Cantal, and Velay. The tertiary formations of England are, in fact, almost exclusively of mechanical origin, and their composition bespeaks the absence of those mineral and thermal waters to which we have attributed the origin of the compact and siliceous limestones, the gypsum, and beds of pure flint, common to the Paris basin and Central France.

English tertiary strata conformable to the chalk.—The British Eocene strata are nearly conformable to the chalk on which they rest, being horizontal where the strata of the chalk are horizontal, and vertical where they are vertical. On the other hand, there are evident signs that the surface of the chalk had, in many places, been furrowed by the action of the waves and currents, before the Plastic clay and its sands were superimposed. In the quarries near Rochester and Gravesend, for instance, fine examples are seen of deep indentations on the surface of the chalk, into which sand, together with rolled and angular pieces of chalk-flint, have been swept *. But these appearances may be referred to the action of water when the chalk began to emerge during the Eocene period, and they by no means warrant the conclusion, that the chalk had undergone any considerable change of position before the tertiary strata were superimposed.

In this respect there is a marked difference between the reciprocal relations of our secondary and tertiary rocks and those which exist between the same groups throughout the greater part of the continent, especially in the neighbourhood of mountain-chains. Near the base, for example, of the Alps,

* Con. and Phil., Outlines of Geol., p. 62.

Apennines, and Pyrenees, we find the newer formations reposing unconformably upon the truncated edges of the older beds, and it is clear that, in many cases, the latter had been subjected to a complicated series of movements before the more modern strata were formed. The latter rise only to a certain height on the flanks of the mountains which usually tower above them, and are recognized at once by the geologist as having been upraised into land when the tertiary formations were still forming in the sea. The ancient borders also of that sea can often be defined with certainty, and the outline of some of its bays and sea-cliffs traced.

In England, although undoubtedly the greater portion of the tertiary strata is confined to certain spaces, we find outlying patches here and there at great distances beyond the general limits, and at great heights upon the chalk which separates the basins of London and Hampshire*. I have seen masses of clay extending in this manner to near the edge of the western escarpment of the chalk in Wiltshire, and Mr. Mantell has pointed out the same to me in the South Downs. Near the escarpment at Lewes, for example, there is a fissure in the chalk filled with sand, and with a ferruginous breccia, such as usually marks the lower members of the Plastic clay formation. From the fact of these tertiary outliers Dr. Buckland inferred, 'that the basins of London and Hants were originally united together in one continuous deposit across the now intervening chalk of Salisbury Plain in Wilts, and the plains of Andover and Basingstoke in Hants, and that the greater integrity in which the tertiary strata are preserved within the basins has resulted from the protection which their comparatively low position has afforded them from the ravages of diluvial denudation †.'

We agree so far with this conclusion as to believe that the basins of London and Hampshire were not separated until part of the tertiary strata were deposited, but we do not think it probable that the tertiary beds ever extended continuously over

* Dr. Buckland, Geol. Trans., Second Series, vol. ii. p. 125. † Ibid., p. 126.

those spaces where the outliers above mentioned occur, nor that the comparative thinness of those deposits in the higher chalk countries should be attributed chiefly to the greater degree of denudation which they have there suffered.

Origin of the English tertiary strata.—In explanation of the phenomena above described, we shall endeavour, in the two next chapters, to lay before the reader a view of the series of events which may have produced the leading geological and geographical features of the south-east of England.

A preliminary outline of these views may be useful in this place. We conceive that the chalk, together with many subjacent rocks, may have remained undisturbed and in horizontal stratification until after the commencement of the Eocene period. When at length the chalk was upheaved and exposed to the action of the waves and currents, it was rent and shattered, so that the subjacent secondary strata were exposed at the same time to denudation. The waste of these rocks, composed chiefly of sandstone and clay, supplied materials for the tertiary sands and clays, while the chalk was the source of flinty shingle, and of the calcareous matter which we find intermixed with the Eocene clays. The tracts now separating the basins of London and Hampshire were those first elevated, and which contributed by their gradual decay to the production of the newer strata. These last were accumulated in deep submarine hollows, formed probably by the subsidence of certain parts of the chalk, which sank while the adjoining tracts were rising.

CHAPTER XXI.

Denudation of secondary strata during the deposition of the English Eocene formations—Valley of the Weald between the North and South Downs—Map—Secondary rocks of the Weald divisible into five groups—North and South Downs—Section across the valley of the Weald—Anticlinal axis—True scale of heights—Rise and denudation of the strata gradual—Chalk escarpments once sea-cliffs—Lower terrace of 'firestone,' how caused—Parallel ridges and valleys formed by harder and softer beds—No ruins of the chalk on the central district of the Weald—Explanation of this phenomenon—Double system of valleys, the longitudinal and the transverse—Transverse how formed—Gorges intersecting the chalk—Lewes Coomb—Transverse valley of the Adur.

Denudation of the Valley of the Weald.—In order to understand the theory of which we sketched an outline at the close of the last chapter, it will be necessary that the reader should be acquainted with the phenomena of denudation exhibited by the chalk and some of the older secondary rocks in parts of England most nearly contiguous to the basins of London and Hampshire. It will be sufficient to consider one of the denuded districts, as the appearances observable in others are strictly analogous; we shall, therefore, direct our attention to what we may call *the Valley of the Weald*, or the region intervening between the North and South Downs.

Map.—In the coloured map given in Plate V.*, the district alluded to is delineated, and it will be there seen that the southern portion of the basin of London, and the north-eastern limits of that of Hampshire, are separated by a tract of secondary rocks, between 40 and 50 miles in breadth, comprising within it the whole of Sussex and parts of the counties of Kent, Surrey, and Hampshire.

There can be no doubt that the tertiary deposits of the Hampshire basin formerly extended much farther along our southern coast towards Beachy Head, for patches are still

* This map has been chiefly taken from Mr. Greenough's Map of England.

found near Newhaven, and at other points, as will be seen by the map. These are now wasting away, and will in time disappear, as the sea is constantly encroaching and undermining the subjacent chalk.

The secondary rocks, depicted on the map, may be divided into five groups:—

1. *Chalk and Upper green-sand.*—This group is the uppermost of the series; it includes the white chalk with and without flints, and an inferior deposit called, provincially, 'Firestone,' and by English geologists the 'Upper green-sand.' It sometimes consists of loose siliceous sand, containing grains of silicate of iron, but often of firm beds of sandstone and chert.
2. Blue clay or calcareous marl, called provincially *Gault.*
3. *Lower green-sand*, a very complex group consisting of grey, yellowish, and greenish sands, ferruginous sand and sandstone, clay, chert, and siliceous limestone.
4. *Weald clay*, composed for the most part of clay without intermixture of calcareous matter, but sometimes including thin beds of sand and shelly limestone.
5. *Hastings sands*, composed chiefly of sand, sandstone, clay, and calcareous grit, passing into limestone *.

The first three formations above enumerated are of marine origin, the last two, Nos. 4 and 5, contain almost exclusively the remains of fresh-water and amphibious animals. But it is not our intention at present to enlarge upon the organic remains of these formations, as we have merely adverted to the rocks in order that we may describe the changes of position which they have undergone, and the denudation to which they have been exposed since the commencement of the Eocene period,—mutations which, if our theory be well founded, belong strictly to the history of *tertiary* phenomena.

By a glance at the map, the reader may trace at once the

* For an account of these strata in the south-east of England, see Mantell's Geology of Sussex, and Dr. Fitton's Geology of Hastings, where the memoirs of all the writers on this part of England are referred to.

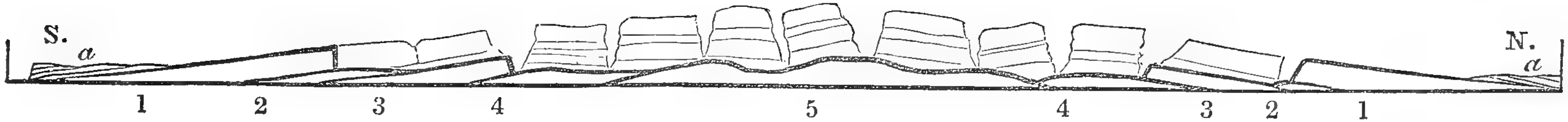
superficial area occupied by each of the five formations above mentioned. On the west will be seen a large expanse of chalk, from which two branches are sent off; one through the hills of Surrey and Kent to Dover, forming the ridge called the North Downs, the other through Sussex to the sea at Beachy Head, constituting the South Downs. The space comprised between the North and South Downs, or ‘the Valley of the Weald,’ consists of the formations Nos. 2, 3, 4, 5, of the above table. It will be observed that the chalk terminates abruptly, and with a well-defined line towards the country occupied by those older strata. Within that line is a narrow band coloured blue, formed by the gault, and within this again is the Lower green sand, next the Weald clay, and then, in the centre of the district, a ridge formed by the Hastings sands.

Section of the Valley of the Weald.—It has been ascertained by careful investigation, that if a line be drawn from any part of the North to the South Downs, which shall pass through the central group, No. 5, the beds will be found arranged in the order described in the annexed section (No. 63, p. 288).

We refer the reader at present to the dark lines of the section, as the fainter lines represent portions of rock supposed to have been carried away by denudation.

At each end of the diagram the tertiary strata *a* are exhibited reposing on the chalk. In the centre are seen the Hastings sands (No. 5), forming an anticlinal axis, on each side of which the other formations are arranged with an opposite dip. It has been necessary however, in order to give a clear view of the different formations, to exaggerate the proportional height of each in comparison to its horizontal extent, and we have subjoined a true scale in another diagram (No. 64) in order to correct the erroneous impression which might otherwise be made on the reader's mind. In this section the distance between the North and South Downs is represented to exceed 40 miles; for we suppose the valley of the Weald to be here intersected in its longest diameter, in the direction of a line between Lewes and Maidstone.

No. 63.

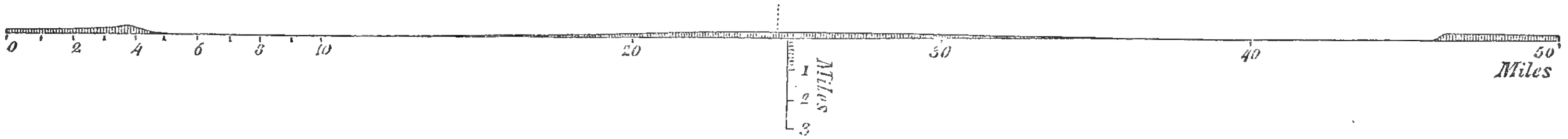


Section from the London to the Hampshire basin across the Valley of the Weald.

a, Tertiary strata. 1, Chalk and firestone. 2, Gault. 3, Lower green-sand. 4, Weald clay. 5, Hastings sands.

No. 64.

Highest point of South Downs, 858 feet. Anticlinal axis of the Weald. Crowborough Hill, 804 feet. Highest point of North Downs, 880 feet *.



Section of the country from the confines of the basin of London to that of Hants, with the principal heights above the level of the sea on a true scale.†

* Lieutenant H. Murphy, R. E., informs me that Botley Hill, near Godstone, in Surrey, was found by trigonometrical measurement to be 880 feet above the level of the sea; and Wrotham Hill, near Maidstone, which appears to be next in height of the North Downs, 795 feet.

† My friend Mr. Mantell, of Lewes, has kindly drawn up this scale at my request.

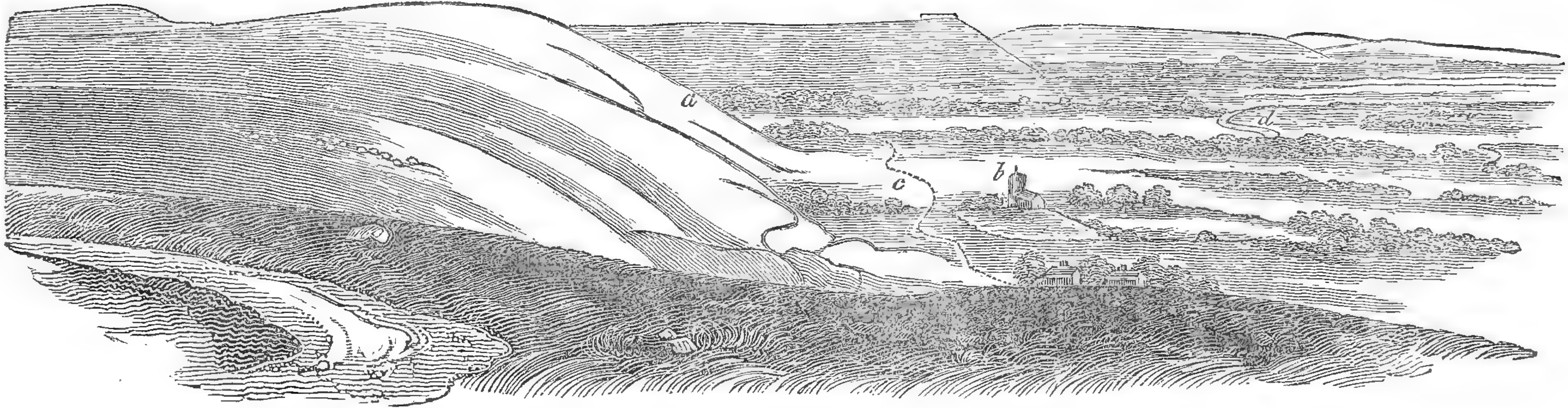
In attempting to account for the manner in which the five secondary groups above mentioned may have been brought into their present position, the following hypothesis has been very generally adopted. Suppose the five formations to lie in horizontal stratification at the bottom of the sea; then let a movement from below press them upwards into the form of a flattened dome, and let the crown of this dome be afterwards cut off, so that the incision should penetrate to the lowest of the five groups. The different beds would then be exposed on the surface in the manner exhibited in the map, plate 5 *.

It will appear from former parts of this work, that the amount of elevation here supposed to have taken place is not greater than we can prove to have occurred in other regions within geological periods of no great duration. On the other hand, the quantity of denudation or removal by water of vast masses which are assumed to have once reached continuously from the North to the South Downs is so enormous, that the reader may at first be startled by the boldness of the hypothesis. But he will find the difficulty to vanish when once sufficient time is allowed for the gradual and successive rise of the strata, during which the waves and currents of the ocean might slowly accomplish an operation, which no sudden diluvial rush of waters could possibly have effected.

Escarpments of the chalk once sea-cliffs.—In order to make the reader acquainted with the physical structure of the Valley of the Weald, we shall suppose him first to travel southwards from the London basin. On leaving the tertiary strata he will first ascend a gently-inclined plane, composed of the upper flinty portion of the chalk, and then find himself on the summit of a declivity consisting, for the most part, of different members of the chalk formation, below which the upper green-sand, and sometimes also the gault *crop out* †. This steep declivity is called by geologists 'the escarpment of the chalk,' which overhangs a

* See illustrations of this theory by Dr. Fitton, Geol. Sketch of Hastings.

† We use this term, borrowed from our miners, to express the coming up to the surface of one stratum from beneath another.



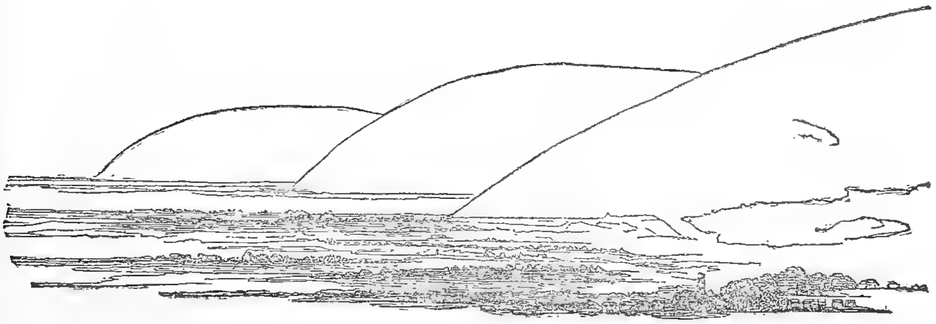
View of the chalk escarpment of the South Downs. Taken from the Devil's Dike, looking towards the west and south-west.

a, The town of Steyning is hidden by this point. *b*, Edburton church. *c*, Road. *d*, River Adur.

valley excavated chiefly out of the argillaceous or marly bed, termed Gault (No. 2). The escarpment is continuous along the southern termination of the North Downs, and the reader may trace it from the sea at Folkstone, westward to Guildford and the neighbourhood of Petersfield, and from thence to the termination of the South Downs at Beachy Head. In this precipice or steep slope the strata are cut off abruptly, and it is evident that they must originally have extended farther. In the accompanying wood-cut (No. 65), part of the escarpment of the South Downs is faithfully represented, where the denudation at the base of the declivity has been somewhat more extensive than usual, in consequence of the upper and lower green-sand being formed of very incoherent materials, the former, indeed, being extremely thin and almost wanting.

The geologist cannot fail to recognize in this view the exact likeness of a sea-cliff, and if he turns and looks in an opposite direction, or eastward, towards Beachy Head, he will see the same line of height prolonged. Even those who are not accustomed to speculate on the former changes which the surface has undergone, may fancy the broad and level plain to resemble the flat sands which were laid dry by the receding tide, and the different projecting masses of chalk to be the headlands of a coast which separated the different bays from each other.

No. 66.

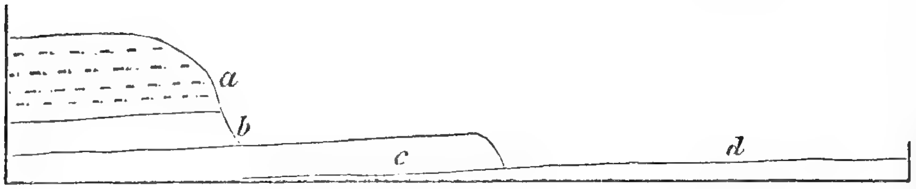


Chalk escarpment as seen from the hill above Steyning, Sussex. The castle and village of Bramber in the fore-ground.

Lower terrace of firestone.—We have said that the upper

green-sand ('firestone,' or 'malm rock,' as it is sometimes called) is almost absent in the tract here alluded to. It is, in fact, seen at Beachy Head to thin out to an inconsiderable stratum of loose green-sand; but farther to the westward it is of great thickness, and contains hard beds of blue chert and limestone. Here, accordingly, we find that it produces a corresponding influence on the scenery of the country, for it runs out like a step beyond the foot of the chalk-hills, and constitutes a lower

No. 67.



a, Chalk with flints. *b*, Chalk without flints.
c, Upper green sand, or firestone. *d*, Gault.

terrace varying in breadth from a quarter of a mile to three miles, and following the sinuosities of the chalk escarpment *.

It is impossible to desire a more satisfactory proof that the escarpment is due to the excavating power of water during the gradual rise of the strata. For we have shown, in our account of the coast of Sicily †, in what manner the encroachments of the sea tend to efface that succession of terraces which must otherwise result from the successive rises of a coast preyed upon by the waves. During the interval between two elevatory movements, the lower terrace will usually be destroyed, wherever it is composed of incoherent materials; whereas the sea will not have time entirely to sweep away another part of the same terrace, or lower platform, which happens to be composed of rocks of a harder texture and capable of offering a firmer resistance to the erosive action of water.

Valleys where softer strata, ridges where harder crop out.—It is evident that the Gault No. 2 (see the map) could not have opposed any effectual resistance to the denuding force

* Mr. Murchison, Geol. Sketch of Sussex, &c., Geol. Trans., 2nd Series, vol. ii. p. 98.
† See p. 111, and wood-cut No. 24.

of the waves; its outcrop, therefore, is marked by a valley, the breadth of which is often increased by the loose incoherent nature of the uppermost beds of the lower green-sand, which lie next to it, and which have often been removed with equal facility.

The formation last mentioned has been sometimes entirely smoothed off like the gault; but in those districts where chert, limestone, and other solid materials enter largely into its composition, it forms a range of hills parallel to the chalk, which sometimes rival the escarpment of the chalk itself in height, or even surpass it, as in Leith Hill. This ridge often presents a steep escarpment towards the Weald clay which crops out from under it. (See the strong lines in diagram No. 63, p. 288.)

The clay last mentioned forms, for the most part, a broad valley, separating the lower green-sand from the Hastings sands, or Forest ridge; but where subordinate beds of sandstone of a firmer texture occur, the uniformity of the plain is broken by waving irregularities and hillocks *.

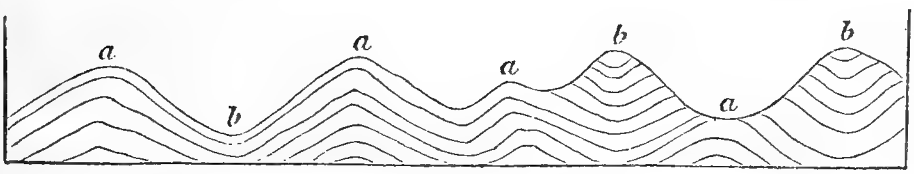
In the central region, or Forest ridge, the strata have been considerably disturbed and are greatly fractured and shifted. One fault is known where the vertical shift of a bed of calcareous grit is no less than 60 fathoms †. It must not be supposed that the anticlinal axis, which we have described as running through the centre of the weald, is by any means so simple as is usually represented in geological sections. There are, on the contrary, a series of anticlinal and synclinal ‡

* Martin, Geol. of Western Sussex. Fitton, Geol. of Hastings, p. 31.

† Fitton, ibid., p. 55.

‡ We adopt this term, first used, we believe, by Professor Sedgwick; its signification will best be understood by reference to the accompanying diagram.

No. 68.



a, Anticlinal lines. *b*, Synclinal lines.

lines, which form ridges and troughs running nearly parallel to each other.

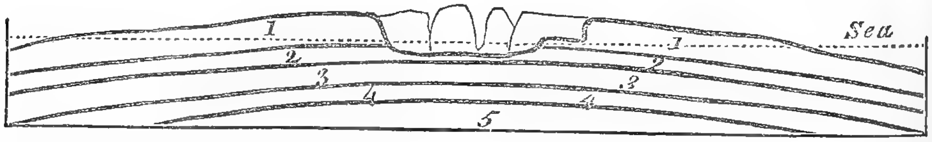
Much of the picturesque character of the scenery of this district arises from the depth of the narrow valleys and ridges to which the sharp bends and fractures of the strata have given rise; but it is also in part to be attributed to the excavating power exerted by water, especially on the interstratified argillaceous beds.

From the above description it will appear that, in the tract intervening between the North and South Downs, there are a series of parallel valleys and ridges; the valleys appearing evidently to have been formed principally by the removal of softer materials, while the ridges are due to the resistance offered by firmer beds to the destroying action of water.

Rise and denudation of the strata gradual.—Let us then consider how far these phenomena agree with the changes which we should naturally expect to occur during the gradual rise of the secondary strata. Suppose the line of the most violent movements to have coincided with what is now the central ridge of the Weald Valley; in that case, the first land which emerged must have been situated where the Forest ridge is now placed. Here a number of reefs may have existed, and islands of chalk, which may have been gradually devoured by the ocean in the same manner as Heligoland and other European isles have disappeared in modern times, as related in our first volume*.

Suppose the ridge or dome first elevated to have been so rent and shattered on its summit as to give more easy access to the waves, until at length the masses represented by the fainter lines in the annexed diagram were removed. Two strips of land might

No. 69.

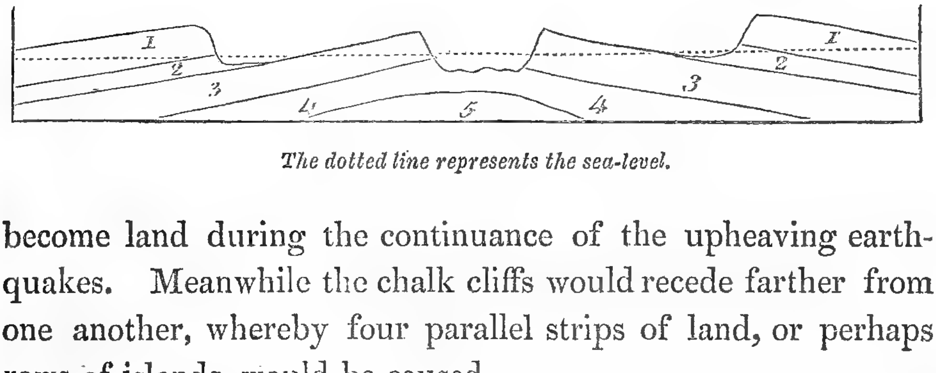


then remain on each side of a channel, in the same manner as

* Page 289, and Second Edition, page 330.

the opposite coasts of France and England, composed of chalk, present ranges of white cliffs facing each other. A powerful current might then rush, like that which now ebbs and flows through the straits of Dover, and might scoop out a channel in the gault. We must bear in mind that the intermittent action of earthquakes would accompany this denuding process, fissuring rocks, throwing down cliffs, and bringing up, from time to time, new stratified masses, and thus greatly accelerating the rate of waste. If the lower bed of chalk on one side of the channel should be harder than on the other, it would cause an under terrace, as represented in the above diagram, resembling that presented by the upper green-sand in parts of Sussex and Hampshire. When at length the gault was entirely swept away from the central parts of the channel, the lower green-sand (3, diagram No. 70,) would be laid bare, and portions of it would

No. 70.



The dotted line represents the sea-level.

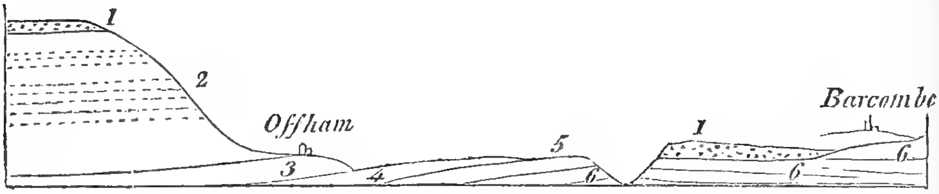
become land during the continuance of the upheaving earthquakes. Meanwhile the chalk cliffs would recede farther from one another, whereby four parallel strips of land, or perhaps rows of islands, would be caused.

The edges of the argillaceous strata, No. 2, are still exposed to erosion by the waves, and a portion of the clay, No. 4, is already removed. This clay, as it gradually rises, will be swept off from part of the subjacent group, No. 5, which will then be laid bare, and may afterwards become land by subsequent elevation.

Why no ruins of chalk on central district.—By this theory of the successive emergence and denudation of the groups, 1, 2, 3, 4, 5, we may account for an alluvial phenomenon which seems inexplicable on any other hypothesis. The summits of the chalk downs are covered everywhere with flint gravel, which

is often entirely wanting on the surface of the clay at the foot of the chalk escarpment, and no traces of chalk flint have ever been found in the alluvium of the central district, or Forest ridge. It is rare, indeed, to see any wreck of the chalk, even at the distance of two or three miles from the escarpments of the North and South Downs. To this general rule, however, an exception occurs near Barcombe, about three miles to the north of Lewes, where we obtain the accompanying section *.

No. 71.



Section from the North escarpment of the South Downs to Barcombe.

1, Gravel composed of partially-rounded chalk flints.
2, Chalk with and without flints.
3, Lowest chalk or chalk marl (upper green-sand wanting).
4, Gault. 5, Lower green-sand. 6, Weald clay.

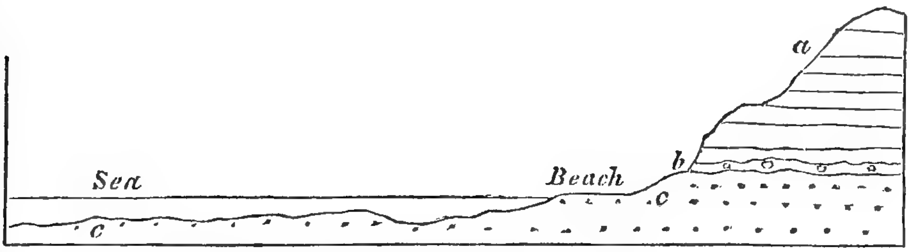
It will be seen that the valley at the foot of the escarpment extends, in this case, not only over the gault, but over the 'lower green-sand' to the Weald clay. On this clay a thick bed of flints, evidently derived from the waste of chalk, remains in the position above described.

We say that there is no detritus of the chalk and its flints on the central ridge of the Weald. I have sought in vain for a vestige of such fragments, and Mr. Mantell, who has had greater opportunities of minute investigation, assures me that he has never been able to detect any. Now whether we embrace or reject the theory of the former continuity of the chalk and other groups over the whole space intervening between the North and South Downs, we cannot certainly imagine that any transient and tumultuous rush of waters could have swept over this country, which should not have left some fragments

* The author visited this locality with Mr. Mantell, to whom he is indebted for this section.

of the chalk and its flints in the deep valleys of the Forest ridge. Indeed, if we adopted the diluvial hypothesis of Dr. Buckland, we should expect to find vast heaps of broken flints drifted more frequently into the valleys of the Gault and Weald clay, instead of being so frequently confined to the summit of the chalk downs. On the other hand, it is quite conceivable that the slow agency of oceanic currents may have cleared away, in the course of ages, the matter which fell into the sea from wasting cliffs. The reader will recollect our account of the manner in which the sea has advanced, within the last century, upon the Norfolk coast at Sherringham *.

No. 72.



Section of cliffs west of Sherringham.

a, Crag. *b*, Ferruginous flint breccia on the surface of the chalk. *c*, Chalk with flints.

The beach, at the foot of the cliff, is composed of bare chalk with flints, as is the bed of the sea near the shore. No one would suspect, from the appearance of the beach at low water, that a few years ago beds of solid chalk, together with sand and loam of the superincumbent crag, formed land on the very spot where the waves are now rolling; still less that these same formations extended, within the last 50 years, to a considerable distance from the present shore, over a space where the sea has now excavated a channel 20 feet deep.

As in this recent instance the ocean has cleared away part of the chalk, and its capping of crag, so the tertiary sea may have swept away not only the chalk, but the layer of broken flints on its surface, which was probably a marine alluvium of the

* Vol. i. p. 268, and Second Edition, p. 307.

Eocene period. Hence these flints might naturally occur on the downs, and be wanting in the valleys below.

If the reader will refer to the preceding diagrams (Nos. 69 and 70), and reflect not only on the successive states of the country there delineated, but on all the intermediate conditions which the district must have passed through during the process of elevation and denudation before supposed, he will understand why no wreck of the chalk (No. 1) should occur at great distances from the chalk escarpments. For it is evident that when the ruins of the uppermost bed (No. 1, diagram 69) had been thrown down upon the surface of the bed immediately below, those ruins would subsequently be carried away when this inferior stratum itself was destroyed. And in proportion to the number and thickness of the groups, thus removed in succession, is the probability lessened of our finding any remnants of the highest group strewed over the bared surface of the lowest.

Transverse valleys.—There is another peculiarity in the geographical features of the south-east of England which must not be overlooked when we are considering the action of the denuding causes. By reference to the map (Plate 5), the reader will perceive that the drainage of the country is not effected by water-courses following the great valleys excavated out of the argillaceous strata (Nos. 2 and 4), but by valleys which run in a transverse direction, passing through the chalk to the basin of the Thames on the one side, and to the English channel on the other.

In this manner the chain of the North Downs is broken by the rivers Wey, Mole, Darent, Medway, and Stour; the South Downs by the Arun, Adur, Ouse, and Cuckmere*.

If these transverse hollows could be filled up, all the rivers, observes Mr. Conybeare, would be forced to take an easterly course, and to empty themselves into the sea by Romney Marsh and Pevensey levels†.

* Conybeare, Outlines of Geol., p. 81. † Ibid., p. 145.

Mr. Martin has suggested that the great cross fractures of the chalk which have become river channels have a remarkable correspondence on each side of the valley of the Weald; in several instances the gorges in the North and South Downs appearing to be directly opposed to each other. Thus, for example, the defiles of the Wey, in the North Downs, and of the Arun in the South, seem to coincide in direction; and, in like manner, the Ouse is opposed to the Darent, and the Cuckmere to the Medway *. But we think it very possible that these coincidences may be accidental. It is, however, by no means improbable, as hinted by the author above mentioned, that the great amount of elevation towards the centre of the Weald district gave rise to transverse fissures. And as the longitudinal valleys were connected with that linear movement which caused the anticlinal lines running east and west, so the cross fissures might have been occasioned by the intensity of the upheaving force towards the centre of

No. 73.

Transverse valley of the Adur in the South Downs.

a, Town of Steyning. b, River Adur. c, Old Shoreham.

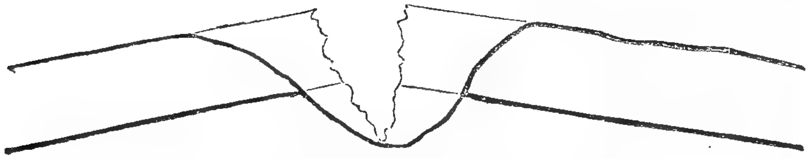
* Geol. of Western Sussex, p. 61.

the line, whereby the effect of a double axis of elevation was in some measure produced.

In order to give a clearer idea of the manner in which the chalk-hills are intersected by these transverse valleys, we subjoin a sketch (No. 73) of the gorge of the river Adur, taken from the summit of the chalk-downs, at a point in the bridle-way leading from the towns of Bramber and Steyning to Shoreham. If the reader will refer again to the view given in a former wood-cut (No. 65, p. 290), he will there see the exact point where the gorge, of which we are now speaking, interrupts the chalk escarpment. A projecting hill, at the point *a*, hides the town of Steyning, near which the valley commences where the Adur passes directly to the sea at Old Shoreham. The river flows through a nearly level plain, as do most of the others which intersect the hills of Surrey, Kent, and Sussex; and it is evident that these openings, so far at least as they are due to aqueous erosion, have not been produced by the rivers, many of which, like the Ouse near Lewes, have filled up arms of the sea, instead of deepening the hollows which they traverse.

In regard to the origin of the transverse ravines, there can be no doubt that they are connected with lines of fracture, and perhaps, in some places, there may be an anticlinal dip on both sides of the valley, as suggested by a local observer *. But this notion requires confirmation.

No. 74.



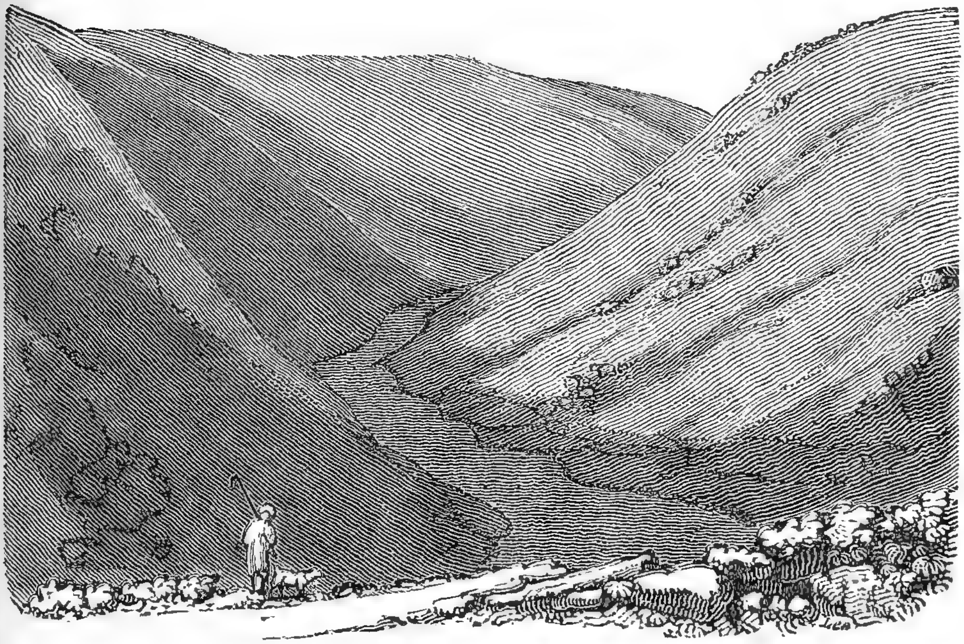
Supposed section of Transverse Valley.

The ravine, called the Coomb, near Lewes, affords a beautiful example of the manner in which narrow openings in the chalk may have been connected with shifts and dislocations in the strata. This coomb is seen on the eastern side of the valley of the Ouse, in the suburbs of the town of Lewes. The steep

* Martin, Geol. of Western Sussex, p. 64, plate III. fig. 3.

declivities on each side are covered with green turf, as is the bottom, which is perfectly dry. No outward signs of disturbance are visible, and the connexion of the hollow with subterranean movements would not have been suspected by the geologist, had not the evidence of great convulsions been clearly exposed in the escarpment of the valley of the Ouse, and in the numerous chalk pits worked at the termination of the

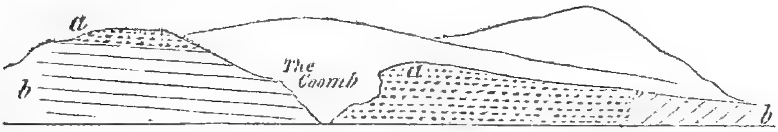
No. 75.



The Coomb, near Lewes.

Coomb. By aid of these we discover that the ravine coincides precisely with a line of fault, on one side of which the chalk with flints *a*, appears at the summit of a hill, while it is thrown down to the bottom on the other.

No. 76.



Fault in the cliff-hills near Lewes.

a, Chalk with flints.　　*b*, Lower chalk*.

The fracture here alluded to is one of those which run east

* I examined this spot in company with Mr. Mantell, to whom I am indebted for the above section.

and west, and of which there are many in the Weald district, parallel to the central axis of the Forest ridge.

In whatever manner the transverse gorges originated, they must evidently have formed ready channels of communication between the submarine longitudinal valleys and those deep parts of the sea wherein we imagine the tertiary strata to have been accumulated. If the strips of land which first rose had been unbroken, and there had been no free passage through the cross fractures, the currents would not so easily have drifted away the materials detached from the wasting cliffs, and it would have been more difficult to understand how the wreck of the denuded strata could have been so entirely swept away from the base of the escarpments.

In the next chapter we shall resume the consideration of these subjects, especially the proofs of the former continuity of the chalk of the North and South Downs, and the probable connexion of the denudation of the Weald valley with the origin of the Eocene strata.

CHAPTER XXII.

Denudation of the Valley of the Weald, *continued*—The alternative of the proposition that the chalk of the North and South Downs were once continuous, considered—Dr. Buckland on the Valley of Kingsclere—Rise and denudation of secondary rocks gradual—Concomitant deposition of tertiary strata gradual—Composition of the latter such as would result from the wreck of the secondary rocks—Valleys and furrows on the chalk how caused—Auvergne, the Paris basin, and south-east of England one region of earthquakes during the Eocene period—Why the central parts of the London and Hampshire basins rise nearly as high as the denudation of the Weald—Effects of protruding force counteracted by the levelling operations of water—Thickness of masses removed from the central ridge of the Weald—Great escarpment of the chalk having a direction north-east and south-west—Curved and vertical strata in the Isle of Wight—These were convulsed after the deposition of the fresh-water beds of Headen Hill—Elevations of land posterior to the crag—Why no Eocene alluviums recognizable—Concluding remarks on the intermittent operations of earthquakes in the south-east of England, and the gradual formation of valleys—Recapitulation.

Extent of denudation in the Valley of the Weald.—'It would be highly rash,' observes Mr. Conybeare, speaking of the denudation of the Weald, 'to assume that the chalk at any period actually covered the whole space in which the inferior strata are now exposed, although the truncated form of its escarpment evidently shows it to have once extended much farther than at present *.'

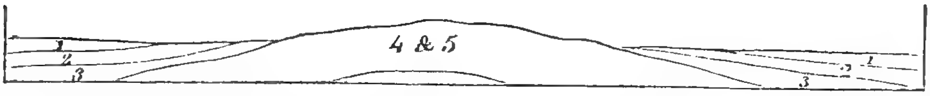
We believe that few geologists who have considered the extent of country supposed to have been denuded, and who have explored the hills and valleys of the central, or Forest ridge, without being able to discover the slightest vestige of chalk in the alluvium †, will fail to participate, at first, in the doubts here expressed as to the original continuity of the upper secondary formations over the anticlinal axis of the Weald. For our own part, we never traversed the wide space which separates the North and South Downs, without desiring to escape from the conclusions advocated in the last chapter; and yet we have

* Outlines, p. 144. † See above, p. 295.

been invariably brought back again to the opinion, that the chalk was originally continuous, on a more deliberate review of the whole phenomena.

It may be useful to consider the only other alternative of the hypothesis before explained. If the marine groups, Nos. 1, 2, 3, were not originally continuous, it is necessary to imagine

No. 77.



1, Chalk and Upper green-sand. 2, Gault. 3, Lower green-sand. } Marine.
4, Weald clay. 5, Hastings sands. } Fresh-water.

that they each terminated at some point between their present outgoings and the secondary strata of the Forest ridge. Thus we might suppose them to have thinned out one after the other, as in the above diagram, and never to have covered the entire area occupied by the fresh-water strata, Nos. 4 and 5.

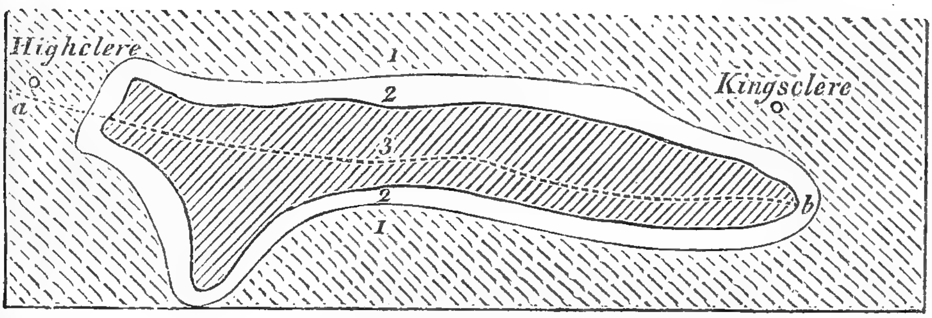
We grant that had such been the original disposition of the different groups, they might, as they gradually emerged from the sea, have become denuded in the manner explained in the last chapter, so that the country might equally have assumed its present configuration. But, although we know of no invincible objection to such an hypothesis, there are certainly no appearances which favour it. If the strata Nos. 4 and 5 had been unconformable to the Lower green-sand No. 3, then, indeed, we might have imagined that the older groups had been disturbed by a series of movements antecedently to the deposition of No. 3, and, in that case, some parts of them might be supposed to have emerged or formed shoals in the ancient sea, interrupting the continuity of the newer marine deposits. But the group No. 4 is *conformable* to No. 3, and the only change which has been observed to take place at the junction, is an occasional intermixture of the Weald clay with the superior marine sand, such as might have been caused by a slight superficial movement in the waters when the sea first overflowed the fresh-water strata.

On the other hand, the green-sand and chalk, as they approach the central axis of the Weald, are not found to contain littoral shells, or any wreck of the fresh-water strata, such as might indicate the existence of an island with its shores or wasting cliffs. Had any such signs been discovered, we might have been inclined to suppose the geography of the region to have once borne some resemblance to that exhibited in the diagram No. 77.

Dr. Buckland on Valleys of Elevation.—We are indebted to Dr. Buckland for an able memoir in illustration of several districts of similar form and structure to the Weald, which occur at no great distance in the south of England. His paper is intitled, 'On the formation of the Valley of Kingsclere and other valleys by the elevation of the strata which enclose them *.'

The valley of Kingsclere, situate a few miles south of New-

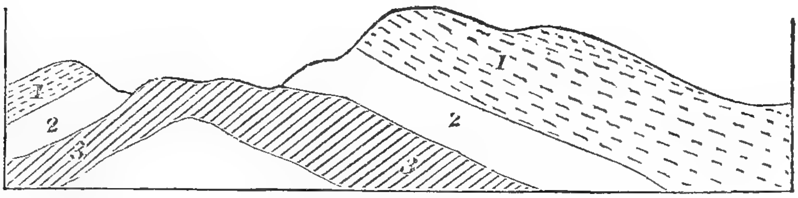
No. 78.



Valley of Kingsclere.

a, b, Anticlinal line marking the opposite dip of the strata on each side of it.

No. 79.



Section across the Valley of Kingsclere from north to south.

1, Chalk with flints. 2, Lower chalk without flints.
3, Upper green-sand, or firestone, containing beds of chert.

* Geol. Trans., 2nd Series, vol. ii. p. 119.

bury, in Berkshire, is about five miles long and two in breadth. The upper and lower chalk, as will be seen in the accompanying section *, and the upper green-sand dip in opposite directions from an anticlinal axis which passes through the middle of the valley along the line *a, b,* of the ground-plan (No. 78).

We subjoin an additional wood-cut, as conveying a scale of

N. No. 80. S.

Valley of Kingsclere.

heights more nearly approaching to that of nature, although the altitudes, in proportion to the horizontal extent, are even in this, perhaps, somewhat in excess. On each side of the valley we find escarpments of chalk, the strata of which dip in opposite directions, in the northern escarpment to the north, and in the southern to the south. At the eastern and western extremities of the valley, the two escarpments become confluent, precisely in the same manner as do those of the North and South Downs, at the eastern end of the Weald district, near Petersfield. And as, a few miles east of the town last mentioned (see Map, plate V.), the firestone, or upper green-sand, is laid open in the sharp angle between the escarpment of the Alton Hills and the western termination of the South Downs †; so in the valley of Kingsclere the same formation is seen to crop out from beneath the chalk.

The reader might imagine, on regarding Dr. Buckland's section (No. 79), where, for the sake of elucidating the geological phenomena, the heights are greatly exaggerated in proportion to the horizontal extent, that the solution of continuity of the strata bounding the valley of Kingsclere had been simply due to elevation and fracture, unassisted by aqueous causes; but by reference to the true scale (No. 80), it will

* Copied by permission from Dr. Buckland's plate XVII., Geol. Trans., 2nd Series, vol. ii.

† See Mr. Murchison's map, plate XIV., ibid.

immediately appear, that a considerable mass of chalk must have been removed by denudation.

If the anticlinal dip had been confined to the valley of Kingsclere, we might have supposed that the upheaving force had acted on a mere point, forcing upwards the superincumbent strata into a small dome-shaped eminence, the crown of which had been subsequently cut off. But Dr. Buckland traced the line of opposite dip far beyond the confluence of the chalk escarpments, and found that it was prolonged in a more north-west direction far beyond the point *a*, diagram No. 78. In following the line thus extended, the strata are seen in numerous chalk-pits to have an opposite dip on either side of a central axis, from which we may clearly infer the linear direction of the movement. Perhaps the intensity of the disturbing force was greatest where the denudation of the valley of Kingsclere took place; but this cannot be confidently inferred, for the quantity of matter removed by aqueous agency must depend on the set of the tides and currents at the period of emergence, and not solely on the amount of elevation and derangement of the strata.

Many of the valleys enumerated by Dr. Buckland as having a similar conformation to that of Kingsclere, run east and west, like the anticlinal ridge of the Weald valley. Several of these occur in Wiltshire and Dorsetshire, and they are all circumscribed by an escarpment whose component strata dip outwards from an anticlinal line running along the central axis of the valley. One of these, distant about seven miles to the north-east of Weymouth, is nearly elliptical in shape, and in size does not much exceed that of the Coliseum at Rome. Their drainage is generally effected by an aperture in one of their lateral escarpments, and not at either extremity of their longer axis, as would have happened had they been simply excavated by the sweeping force of rapid water *.

'It will be seen,' continues Dr. Buckland, 'if we follow on Mr. Greenough's map the south-western escarpment of the

* Dr. Buckland, Geol. Trans., 2nd Series, vol. ii. p 122.

chalk in the counties of Wilts and Dorset, that, at no great distance from these small elliptical valleys of elevation, there occur several longer and larger valleys, forming deep notches, as it were, in the lofty edge of the chalk. These are of similar structure to the smaller valleys we have been considering, and consist of green-sand, inclosed by chalk at one extremity, and flanked by two escarpments of the same, facing each other with an opposite dip; but they differ in the circumstance of their other and broader extremity being without any such inclosure, and gradually widening till it is lost in the expanse of the adjacent country.

The cases I now allude to are the Vale of Pewsey, to the east of Devizes, that of the Wily, to the east of Warminster, and the valley of the Nadder, extending from Shaftsbury to Barford, near Salisbury; in which last not only the strata of green-sand are brought to the surface, but also the still lower formations of Purbeck and Portland beds, and of Kimmeridge clay.

It might at first sight appear that these valleys are nothing more than simple valleys of denudation; but the fact of the strata composing their escarpments having an opposite and outward dip from the axis of the valley, and this often at a high angle, as near Fonthill and Barford, in the Vale of the Nadder, and at Oare, near the base of Martinsell Hill, in the Vale of Pewsey, obliges us to refer their inclination to some antecedent violence, analogous to that to which I have attributed the position of the strata in the inclosed valleys near Kingsclere, Ham, and Burbage. Nor is it probable that, without some pre-existing fracture or opening in the lofty line of the great chalk escarpment, which is here presented to the north-west, the power of water alone would have forced open three such deep valleys as those in question, without causing them to maintain a more equable breadth, instead of narrowing till they end in a point in the body of the chalk *.

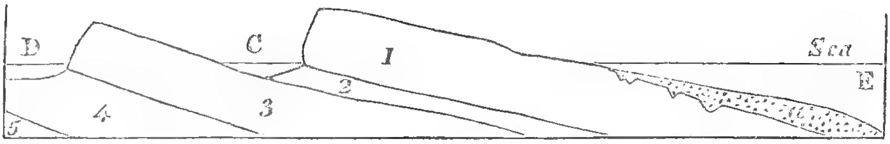
Rise and denudation of the secondary rocks gradual.—To

* Dr. Buckland, Geol. Trans., 2nd Series, vol. ii. p. 123.

return to the valley of the Weald, the strata of the North Downs are inclined to the north, at an angle of from 10° to 15°, and in the narrow ridge of the Hog's back, west of Guildford, in Surrey, about 45°; those in the South Downs dip to the south at a slight angle. It is superfluous to dwell on the analogy which in this respect the two escarpments bear to those which flank the valleys above alluded to; and in regard to the greater distance which separates the hills of Surrey from those of Sussex, the difficulty may be reduced simply to a question of time. If the rise of the land and its degradation by aqueous causes was accomplished by an indefinite number of minor convulsions, during an immense lapse of ages, we behold in the ocean a power fully adequate to perform the work of demolition. If, on the other hand, we embrace the hypothesis of paroxysmal elevation, or, in other words, suppose a submarine tract to have been converted instantaneously into high land, we may seek in vain for any known cause capable of sweeping away even those portions of chalk and other rocks which, all are agreed, must once have formed the prolongation of the existing escarpments. It is common in such cases to call in one arbitrary hypothesis to support another, and as the upheaving force operated with sudden violence, so a vast diluvial wave is introduced to carry away, with almost equal celerity, the mountain mass of strata assumed to have been stripped off.

Materials of the tertiary strata whence derived.—If, then, we conclude that the wreck of the denuded district was *removed* gradually, it follows that it was *deposited* by degrees elsewhere. If any part of the sea immediately adjacent to the district which was then emerging, was of considerable depth, the drift matter would be consigned to that submarine region, since every current charged with sediment must purge itself in the first deep cavity which it traverses, as does a turbid river in a lake. Suppose that while the wave sand currents were excavating the longitudinal valleys, D and C (No. 81, p. 310), the deposits *a* were thrown down to the bottom of the contiguous deep

No. 81.



water E, the sediment being drifted through transverse fissures, as before explained. In this case, the rise of the formations Nos. 1, 2, 3, 4, 5, may have been going on contemporaneously with the excavation of the valleys C and D, and with the accumulation of the strata *a*. There must be innumerable points on our own coast where the sea is of great depth near to islands and cliffs now exposed to rapid waste, and in all these the denuding and reproductive processes must be going on in the immediate proximity of each other. Such may have been the case during the rise of the Valley of the Weald, and the deposition of the beds of the London and Hampshire basins.

The theory above proposed requires that the deposits *a* should be composed, for the most part, of a mixture of such mineral ingredients as would result from the degradation of the secondary groups, Nos. 1, 2, 3, 4, 5. Now the tertiary strata answer extremely well to these conditions. They consist, as we have before seen, of alternations of variously-coloured sands and clays, as do the secondary strata from the group No. 5 to No. 2 inclusive, the principal difference being, that the latter are more consolidated.

If it be asked, where do we find the ruins of the *white chalk* among our Eocene strata? We reply, that the flint pebbles which are associated in such immense abundance with the sands of the plastic clay, are derived evidently from the destruction of chalk; and as to the soft white calcareous matrix, we may suppose it to have been reduced easily to fine sediment, and to have contributed, when in a state of perfect solution, to form the shells of Eocene testacea; or when mixed with the waste of the argillaceous groups, Nos. 2 and 4, which have been peculiarly exposed to denudation, it may have entered into the composition of the London clay, which contains no slight

proportion of calcareous matter. In the crag of Norfolk, undoubtedly, we find great heaps of broken pieces of white chalk, with slightly-worn and angular flints; but in this case we may infer that the attrition was not continued for a long time; whereas the large accumulations of perfectly-rolled shingle, which are interstratified with our Eocene formations, proves that they were acted upon for a protracted period by the waves. We have many opportunities of witnessing the entire demolition of the chalk on our southern coast, as at Seaford, for example, in Sussex, where large masses are, year after year, detached from the cliffs, and soon disappear, leaving nothing behind but a great bank of flint shingle *.

Valleys and furrows in the chalk how caused.—The furrows which occur on the surface of the chalk, filled with sand and pebbles of the plastic clay, may be easily explained if we suppose the English Eocene strata to have been formed during a period of local convulsion. For if portions of the secondary rocks emerged from the sea in the south-east of our island during that period, it is probable that the chalk underwent many oscillations of level, and that certain tracts became land and then sea, and then land again, so that parts of the surface, first excavated by currents or rivers, were occasionally submerged, and, after being covered by tertiary deposits, upraised again. We must also remember, that almost every part of the chalk must have been exposed for some time to the action of the waves, if we assume the elevation to have been slow and by successive movements. The valleys seen everywhere on the surface, and the layers of partially-rolled and broken flints which very generally overspread it, may be referred to the sea breaking upon the reefs and shoals when the rocks were about to emerge. We apprehend, indeed, that no formidable difficulty will be encountered in explaining the position of the tertiary sand which sometimes fills rents and furrows in the chalk, or the occurrence of banks of shingle at the junction of the tertiary strata and the chalk, if we once admit that the

* Vol. i. p. 279, and Second Edition, p. 319.

Eocene deposits originated while the chalk and other secondary rocks were rising from the deep and wasting away.

Earthquakes during the Eocene period.—We have pointed out, in a former chapter, our reasons for concluding that the Paris basin was a theatre of subterranean convulsions during the Eocene period, the older beds of the calcaire grossier having been raised and exposed to the action of the waves before, or at least during, the deposition of the upper or second marine group *. These convulsions were doubtless connected with that depression which let in the sea upon the second fresh-water formation, and gave rise to the superposition of the upper marine beds. We have also demonstrated, in a preceding chapter, that some of the earlier volcanic eruptions in Auvergne happened before the Eocene species of animals were extinct, and we suggested that the great lakes of Central France may have been drained by alterations of level which accompanied the outbreak of those earlier Eocene volcanos of Auvergne. We ought not, therefore, to be surprised if we discover proofs that the south-east of England participated in the earthquakes which seem to have extended at that time over a considerable part of the neighbouring continent; and we may refer the alternation of marine and fresh-water beds in the Isle of Wight and coast of Hampshire, to changes of level analogous to those which gave rise to the intercalation of the upper marine formation in the Paris basin.

Why the English Eocene strata rise nearly as high as the denuded secondary districts. — Those geologists who have hitherto regarded the rise and denudation of the lands in the south-east of England as events posterior in date to the deposition of the London clay, will object to the foregoing reasoning, that not only certain outlying patches of tertiary strata, but even the central parts of the London and Hampshire basins, attain very considerable altitudes above the level of the sea. Thus the London clay at Highbeach, in Essex, reaches the height of 750 feet, an elevation exceeding that

* See above, p. 248.

of large districts of the chalk and other denuded secondary rocks. But these facts do not, we think, militate against the theory above proposed, for we have assumed a long-continued series of elevatory movements in a region where the degradation and reproduction of strata were in progress.

If this be granted, it is evident that the great antagonist powers, the igneous and the aqueous, would, throughout the whole period, be brought into play in their fullest energy, the igneous labouring continually to produce the greatest inequality of surface, by uplifting certain lines of country and depressing others ; the aqueous no less incessantly engaged in reducing the whole to a level, by cutting off the summits of the upraised tracts, and throwing the materials thence removed into the adjoining hollows. If the volcanic forces eventually prevail, so as to convert the whole region into land, we must expect that some of the materials drifted into the hollows, and forming the newer strata, will be brought up to view, while the denuded districts are raised at the same time. If these last continue, *in general*, to occupy a higher position above the level of the sea, it is all that can be expected after the levelling operations before alluded to.

Now the tracts occupied by our Eocene formations are low, not so much with reference to the secondary rocks which remain, as to these masses which must be supposed by our theory to have disappeared, having been carried away by denudation. Let the portions removed from the space intervening between the North and South Downs, and which are expressed by faint lines in our section, wood-cut No. 63, be restored, and we may readily conceive that those masses may have formed shoals and dry land for ages before any part of our tertiary basins emerged.

The estimate of Mr. Martin is not, perhaps, exaggerated, when he computes the probable thickness of strata removed from the highest part of the Forest ridge to be about 1900 feet. So that if we restore to Crowborough Hill, in Sussex, the beds of Weald clay, Lower green-sand, Gault, and chalk,

which have been removed by denudation, that hill, instead of rising to the height of 800 feet, would be more than trebled in altitude *, and be about 2700 feet high. It would then tower far above the highest outlyers of tertiary strata which are scattered over our chalk, for Inkpen Hill, the greatest elevation of chalk in England, rises only 1011 feet above the level of the sea.

Some geologists who have thought it necessary to suppose all the strata of the London and Hampshire basins to have been once continuous, have estimated the united thickness of the three marine Eocene groups before described, as amounting to 1300 feet, and have been bold enough to imagine a mass of this height to have been once superimposed upon the chalk which formerly covered the axis of the Weald †. Hence they were led to infer that Crowborough Hill was once 4000 feet high, and was then cut down from 4000 to 800 feet by *diluvial action*.

We, on the contrary, deem it wholly unnecessary to suppose any removal of rocks newer than the secondary from the central parts of the valley of the Weald; and we suppose the waste of the older rocks to have been caused gradually during the emergence of the country. The small strips of land which were first protruded in an open sea above the level of the waves, may have been entirely carried away, again and again, in the intervals between successive movements, until at last a great number of reefs and islands rising at once, afforded protection to each other against the attacks of the waves, and the lands began to increase. We do not conceive, therefore, that a mountain ridge first rose to the height of more than 2000 feet, and was then lowered to less than half that elevation; but that a stratified mass, more than 2000 feet thick, was, by the continual stripping off of the uppermost beds as they rose, diminished to a thickness of about 800 feet.

It is not our intention, at present, to point out the applica-

* Phil. Mag. and Annals, No. 26, New Series, p. 117.

† Martin, ibid.

tion of the above theory to the region immediately westward of the great line of chalk escarpment which runs through the central parts of England from Dorsetshire to Cambridgeshire. The denudation in that country has doubtless been on a great scale, and was, perhaps, effected during the Eocene period; for we know of no reason why one line of movements should not have been in progress in a direction north-east and south-west, while others were heaving up the strata in lines running east and west. We may remark, at the same time, that if the chalk in the interior of England, in those tracts from which it has been extensively swept away, began to rise during the tertiary epoch, and before the emergence of the chalk which once extended over the central axis of the Weald, some tertiary deposits may, in that case, have been thrown down upon that central ridge. We have at present, however, no data to lend countenance to such conjectures.

Vertical strata of the Isle of Wight.—A line of vertical and inclined strata running east and west, or parallel to the central axis of the Weald, extends through the isles of Wight and Purbeck, and through Dorsetshire, and has been observed by Dr. Fitton to reappear in France, north of Dieppe. The same strata which are elevated in the Weald Valley are upheaved also on this line in the centre of the Isle of Wight, where all the tertiary strata appear to have partaken in the same movement *.

From the horizontality of the fresh-water series in Alum Bay, as contrasted with the vertical position of the marine tertiary beds, Mr. Webster was at first led very naturally to conclude, that the latter had undergone great derangement before the deposition of the former. It appears, however, from the subsequent observations of Professor Sedgwick †, that these appearances are deceptive, and that at the eastern

* See Mr. Webster's section, Geol. Trans., vol. ii. First Series, plate XI.

† Anniv. Address to the Geol. Soc., Feb. 1831, p. 9. Professor Sedgwick informs me that his observations, made six years ago, have recently been confirmed by Professor Henslow.

extremity of the Isle of Wight, part of the fresh-water series is vertical, like the marine. Hence it is now ascertained that as the chalk is horizontal at the southern extremity of the Isle of Wight, while it is vertical in the centre of that island, so the Eocene strata are horizontal in the north of the island, and vertical in the centre. We have only to imagine that the great flexure of the secondary and tertiary beds, so ingeniously suggested by Mr. Webster in his theoretical section *, extended to the fresh-water formations, in order to comprehend how a very simple series of movements may have brought the whole of the Isle of Wight groups into their present position.

We are unable to assign a precise date to the convulsions which produced this great curve in the stratified rocks of the Isle of Wight; but we may observe that, although subsequent to the deposition of the fresh-water beds, it does not follow that it was not produced in the Eocene period. It may have been contemporaneous with those movements which raised the central parts of the London and Hampshire basins, which, as we before explained, were subsequent to the principal elevation and denudation of the central axis of the Weald.

Land has certainly been elevated on our eastern coast since the commencement of the older Pliocene period, as is attested by the moderate height attained by the crag strata †. But these changes of level may have been partial, and if the crag does not extend farther over the Eocene formations, and into the Weald Valley, it is probably because those regions were dry land when the strata of crag were forming in the sea.

The first land that rose in the south-eastern extremity of England may have been placed, as we before hinted, where we now find the central axis of elevation in the Weald. Perhaps the chalk islands there formed may have supported that tropical vegetation whereof we find memorials in the fossil

* Englefield's Isle of Wight, plate XLVII. fig. 1.

† We alluded, at p. 182, to the supposed discovery of recent marine shells at the height of 140 feet above the sea in Sheppey; but we have since learnt from Professor Sedgwick, that the information communicated to the Geological Society on this subject was erroneous.

plants of Sheppey; and the shores of those islands may have been frequented, during the ovipositing season, by the turtles and crocodiles, of which the teeth and skeletons are imbedded in the London clay *.

Eocene alluviums.—The river which produced that body of water in which the fresh-water strata of Hampshire originated, must have drained some contiguous lands which may have emerged during the Eocene period. On these lands we may suppose the Paleothere, Anoplothere, and Moschus of Binstead to have lived. The discovery of the two former genera, associated as they are with well-known Eocene species of testacea, is most interesting. It shows that in England, or rather on the space now occupied by part of our island, as well as in the Paris basin, Auvergne, Cantal, and Velay, there were mammalia of a peculiar type during the Eocene period. Yet we have never found a single fragment of the bones of any of these quadrupeds in our alluviums or cave breccias. In these formations we find the bones of the mastodon and mammoth, of the rhinoceros, hippopotamus, lion, hyæna, bear, and other quadrupeds, all of extinct species. They are accompanied by recent fresh-water shells, or by the marine fossils of the crag, and evidently belong to an epoch posterior to the Eocene. Where, then, are the terrestrial alluviums of that surface which was inhabited by the Paleothere and its congeners? Have the remains which were buried at so remote a period decomposed, so that they no longer afford any zoological characters which might enable us to distinguish the Eocene from more modern alluviums?

It seems clear that a peculiar and rare combination of favourable circumstances is required to preserve mammiferous or other remains in terrestrial alluviums in sufficient quantity to afford the geologist the means of assigning the date of such deposits. For this reason we are scarcely able, at present, to form any conjecture as to the relative ages of the numerous

* We have introduced these islands into the map of Europe, in the 2nd volume, which may be supposed to relate to the commencement of the Eocene period.

alluviums which cover the surface of Scotland, a country which probably became land long before the commencement of the tertiary epochs.

Elevation of land gradual.—As we have assumed, throughout this and the preceding chapter, that the elevatory force was developed in a succession of minor convulsions in the south-east of England, we may seem called upon to answer an objection which has been drawn from the verticality of the strata in the Isles of Wight and Purbeck. Mr. Conybeare has remarked, that the vertical strata are traced through a district nearly 60 miles in length, so that '*if* their present position were the effect of a *single convulsion*, no disturbance in the least comparable with it has occurred in modern times *.' As we can by no means dissent from this proposition, we only ask where is the evidence that a *single* effort of the subterranean force, rather than reiterated movements, produced that sharp flexure of which we suppose the vertical strata of the Isle of Wight to form a part, the remainder of the arc having been carried away by denudation.

It appears extremely probable that the Cutch earthquake of 1819, so often alluded to by us †, may have produced an incipient curve, running in a linear direction through a tract at least 60 miles in length. The strata were upraised in the Ullah Bund, and depressed below the level of the sea in the adjoining tract, where the fort of Sindree was submerged. It would be impossible, if the next earthquake should raise the Bund still higher, and sink to a lower depth the adjoining tract, to discriminate, by any geological investigations, the different effects of the two earthquakes, unless a minute survey of the effects of the first shock had been made and put on record. In this manner we may suppose the strata to be bent, again and again, in the course of future ages, until parts of them become perpendicular.

To some it may appear, that there is a unity of effect in the

* Phil. Mag. and Annals, No. 49, new Series, p. 21.

† Vol. i., Second Edition, p. 465, and vol. ii., First Edition, p. 265.

line of deranged strata in the isles of Wight and Purbeck, as also in the central axis of the Weald, which is inconsistent with the supposition of a great number of separate movements recurring after long intervals of time. But we know that earthquakes are repeated throughout a long series of ages, in the same spots, like volcanic eruptions. The oldest lavas of Etna were poured out many thousand, perhaps myriads, of years, before the newest, and yet they have produced a symmetrical mountain; and if rivers of melted matter thus continue to flow in the same direction, and towards the same points, for an indefinite lapse of ages, what difficulty is there in conceiving that the subterranean volcanic force, occasioning the rise or fall of certain parts of the earth's crust, may, by reiterated movements, produce the most perfect unity of result?

Excavation of Valleys.—In our attempt to explain the origin of the existing valleys in the south-east of England, it will be seen that we refer their excavation chiefly to the ocean. We are aware that we cannot generalize these views and apply them to the valleys of all parts of the world. In Central France, for example, rivers and land-floods, co-operating with earthquakes, have deeply intersected the lacustrine and volcanic deposits, and have hollowed out valleys as deep, perhaps, as any in our Weald district. In what manner these effects may be brought about in the course of time, by the action of running water, even without the intervention of the sea, may be understood by what we have said of the removal of rock by aqueous agency during the Calabrian earthquakes *.

Those geologists who contend that the valleys in England are not due to what they term 'modern causes,' are in the habit of appealing to the fact, that the rivers in the interior of England are working no sensible alterations, and could never, in their present state, not even in millions of years, excavate the valleys through which they now flow. We suspect that a false theory is involved even in the term 'modern causes,' as

* Vol. i. chap. xxiv.

if it could be assumed that there were *ancient causes* differing from those which are now in operation. But if we substitute the phrase, existing causes, we shall find that the argument now controverted amounts to little more than this, 'that in a country free from subterranean movements, the action of running water is so trifling that it could never hollow out, in any lapse of ages, a deep system of valleys, and, *therefore*, no known combination of existing causes could ever have given rise to our present valleys!'

The advocates of these doctrines, in their anxiety to point out the supposed absurdity of attributing to ordinary causes those inequalities of hill and dale, which now diversify the earth's surface, have too often kept entirely out of view the many recorded examples of elevations and subsidences of land during earthquakes, the frequent fissuring of mountains, and opening of chasms, the damming up of rivers by landslips, the deflection of streams from their original courses, and more important, perhaps, than all these, the denuding power of the ocean, during the rise of our continents from the deep. Few of the ordinary causes of change, whether igneous or aqueous, can be observed to act with their full intensity in any one place at the same time; hence it is easy to persuade those who have not reflected long and profoundly on the working of the numerous igneous and aqueous agents, that they are entirely inadequate to bring about any important fluctuations in the configuration of the earth's surface.

Recapitulation.—We shall now briefly recapitulate the conclusions to which we have arrived respecting the geology of the south-east of England, in reference to the nature and origin of the Eocene formations considered in this and the two preceding chapters.

1. In the first place, it appears that the tertiary strata rest exclusively upon the chalk, and consist, with some trifling exceptions, of alternations of clay and sand.

2. The organic remains agree with those of the Paris basin, but the *mineral character* of the deposit is extremely different,

those rocks in particular, which are common to the Paris basin and Central France, being wanting, or extremely rare, in the English tertiary formations.

3. The Eocene deposits of England are generally conformable to the chalk, being horizontal where the beds of chalk are horizontal, and vertical where they are vertical; so that both series of rocks appear to have participated in nearly the same movements.

4. It is not possible to define the limits of the ancient borders of the tertiary sea in the south-east of England, in the same manner as can be frequently done in those countries where the secondary rocks are unconformable to the tertiary.

5. Although the tertiary deposits are chiefly confined to the tracts called the basins of London and Hampshire, insulated patches of them are, nevertheless, found on some of the highest summits of the chalk intervening between these basins.

6. These outliers, however, do not necessarily prove that the great mass of tertiary strata was once continuous between the basins of London and Hampshire, and over other parts of the south-east of England now occupied by secondary rocks.

7. On the contrary, it is probable that these secondary districts were gradually elevated and denuded when the basins of London and Hampshire were still submarine, and while they were gradually becoming filled up with tertiary sand and clay.

8. If, in illustration of this theory, we examine one of the districts thus supposed to have been denuded, we find in the Valley of the Weald decided proofs, that since the emergence of the secondary rocks, an immense mass of chalk and subjacent formations has been removed by the force of water.

9. We infer from the existence of large valleys along the outcrop of the softer beds, and of parallel chains of hills where harder rocks come up to the surface, that water was the removing cause; and from the shape of the escarpments presented by the harder rocks, and the distribution of alluvium over different parts of the surface of the Weald district, we

conclude that the denudation was successive and gradual during the rise of the strata.

10. We may suppose that the materials carried away from the denuded district were conveyed into the depths of the contiguous sea, through channels produced by cross fractures which have since become river-channels, and which now intersect the chalk in a direction at right angles to the general axis of elevation of the country.

11. The analogous structure of the Valley of Kingsclere, and other valleys which run east and west, like the Valley of the Weald, but are much narrower, accord also with the hypothesis, that they were all produced by the denuding power of water co-operating with elevatory movements.

12. The mineral composition of the materials thus supposed to have been removed in immense abundance from the Valley of the Weald, are precisely such as would, by degradation, form the English Eocene strata.

13. It is probable that there were many oscillations of level during the Eocene period, so that some tracts were alternately land and then sea, and then land again. These fluctuations may account for the furrowed surface of the chalk on which the tertiary strata sometimes repose, for the valleys on its surface, for the banks of shingle associated with the Plastic clay, for the partial deposits of sand and clay on elevated tracts of chalk, and for the alternations of marine and fresh-water strata in the Hampshire basin.

14. The volcanic eruptions of the Eocene period in Auvergne, the changes of level which took place at the same time in the Paris basin, and those above alluded to in the south-east of England, may all have belonged to one theatre of subterranean convulsion.

15. The basins of London and Hampshire may have been partly formed by subsidences in the bed of the sea, contemporaneously with the elevation and emergence of the Weald district.

16. The movements which threw the chalk and the tertiary strata of the isles of Wight and Purbeck into a vertical position, were subsequent to the formation of the Eocene freshwater strata of the Isle of Wight, but may possibly have occurred during the Eocene period.

17. The masses of secondary rock which have been removed by denudation from the central axis of the Weald would, if restored, rise to more than double the height now attained by any patches of tertiary strata in England.

18. If, therefore, the Eocene strata do not appear to occupy a much lower level than the secondary rocks, from the destruction of which they have been formed, it is because the highest summits of the latter have been cut off during the rise of the land, and thrown into those troughs where we now find the tertiary deposits.

19. The upheaving of the strata of the London and Hampshire basins may have been in great part effected towards the close of the Eocene period; but it must also have been in some part due to the movements which raised the crag.

CHAPTER XXIII.

Secondary formations—Brief enumeration of the principal groups—No species common to the secondary and tertiary rocks—Chasm between the Eocene and Maestricht beds—Duration of secondary periods—Former continents placed where it is now sea—Secondary fresh-water deposits why rare—Persistency of mineral composition why apparently greatest in older rocks—Supposed universality of red marl formations—Secondary rocks why more consolidated—Why more fractured and disturbed—Secondary volcanic rocks of many different ages.

SECONDARY FORMATIONS.

As we have already exceeded the limits originally assigned to this work, it is not our intention to enter, at present, upon a detailed description of the formations usually called 'Secondary,' the elucidation of which might well occupy another volume. By 'secondary,' we mean those stratified rocks older than the tertiary, which contain distinct organic remains, and which sometimes pass into the strata called 'Primary,' to be described in our concluding chapters.

The observations which we are about to offer have chiefly for their object to show that the rules of interpretation adopted by us for the tertiary formations, are equally applicable to the phenomena of the secondary series. This last has been divided into several groups, and we shall briefly enumerate some of the principal of these for the convenience of reference, without pretending to offer to the student a systematic classification, founded on a full comparison of fossil remains.

PRINCIPAL SECONDARY GROUPS. (*Descending Series.*)

1. *Strata from the chalk of Maestricht to the lower green-sand inclusive.*

The number of species of testacea already procured from the different members of this division amount to about 1000. The principal subdivisions are the Maestricht beds, the chalk with and without flints, the upper green-sand, the gault, and

the lower green-sand. The first of these groups is seen at St. Peter's Mount, Maestricht, reposing upon the upper flinty chalk of England and France. It is characterized by a peculiar assemblage of organic remains, perfectly distinct from those of the tertiary period. M. Deshayes, after a careful comparison, and after making drawings of more than 200 species of the Maestricht shells, has been unable to identify any one of them with the numerous tertiary fossils in his collection. On the other hand, there are several shells which are decidedly common to the calcareous beds of Maestricht and the white chalk. The names of twelve of these, communicated by M. Deshayes, will be found in Appendix II., p. 60.

But the fossils of the Maestricht beds extend not merely into the white chalk of the French geologists, but into their 'green-sand,' which appears to correspond very nearly with the upper green-sand of the English geologists. A list of five species of shells, common to the Maestricht beds and the upper green-sand of France, will be found in Appendix II., p. 60.

It will be seen by the above lists, that the belemnite, one of the cephalopodes not found in any tertiary formation, occurs in the Maestricht beds; an ammonite has also been discovered in this group by Dr. Fitton, and is now in the collection of the Geological Society of London.

That gigantic species of reptile, the Mososaurus of Maestricht, has also been found by Mr. Mantell in the English chalk.

2. *The Wealden, or the strata from the Weald clay to the Purbeck limestone inclusive.*

The numerous fossil-shells of this group are referrible to fresh-water genera, which are associated with many remains of fluviatile and terrestrial reptiles and land-plants. We believe that no species, whether animal or vegetable, in this group, has been distinctly identified with any found either in the superincumbent marine beds of the first division, or in the subjacent rocks of the group No. 3, which are also of marine origin.

3. *Oolite, or Jura limestone formation.*

This division, in which we do not include the lias, contains a great number of subordinate members, several of which may relate, perhaps, to periods as important as our subdivisions of the great tertiary epoch. The shells, even of the uppermost part of the series, appear to differ entirely from the species found in the division No. 1.

4. *The Lias.*

The shells of the argillaceous limestone, termed lias, and other associated strata, differ considerably from those of the preceding group, as do the greater number of species of vertebrated animals.

5. *Strata intervening between the Lias and the Carboniferous group.*

The formations which are referrible to the interval which separated the great coal formations from the division last mentioned, are very various, and some of them, like the new red sandstone, contain few organic remains. One group, however, belonging to this period, the Muschelkalk of the Germans, which has no precise equivalent among the English strata, contains many organic remains belonging to species perfectly distinct from the fossils of the lias, and equally so from those of the carboniferous era next to be mentioned.

6. *Carboniferous group, comprising the coal-measures, the mountain limestone, the old red sandstone, the transition limestone, the coarse slates and slaty sandstones called graywacke by some writers, and other associated rocks.*

The mountain and transition limestones of the English geologists contain many of the same species of shells in common, and we shall therefore refer them for the present to the same

great period; and, consequently, the coal, which alternates in some districts with mountain limestone, and the old red sandstone which intervenes between the mountain and transition limestones, will be considered as belonging to the same period. The coal-bearing strata are characterized by several hundred species of plants, which serve very distinctly to mark the vegetation of part of this era. Some of the rocks, termed graywacke in Germany, are connected by their fossils with the mountain limestone.

With this group we shall conclude our enumeration for the present; for although other divisions may hereafter be requisite, we are not aware that any antecedent periods can yet be established on the evidence of a distinct assemblage of fossil remains. Traces of organization undoubtedly occur in rocks more ancient than the transition limestone, and its associated sandstones, called graywacke; but we cannot refer them to a distinct geological period, according to the principles laid down in this work, until we have obtained data for determining the specific characters of a considerable number of fossil remains.

In reviewing the above groups we may first call the reader's attention to the important fact stated on the authority of M. Deshayes, that no species of fossil shells has yet been found common to the secondary and tertiary formations*. This marked discordance in the organic remains of the two series is not confined to the testacea, but extends, so far as a careful comparison has yet been instituted, to all the other departments of the animal kingdom, and to the fossil plants. I am informed by M. Agassiz, whose great work on fossil fish is anxiously looked for by geologists, that after examining about 500 species of that class, in formations of all ages, he could discover no one common to the secondary and tertiary rocks; nay, all the secondary species hitherto known to him, belong to

* M. Deshayes assures me that he has seen no tertiary shells in the Gosau beds, supposed by some geologists to be intermediate between the secondary and tertiary formations; but that some of the most characteristic species of Gosau occur in the green-sand beneath the chalk, at Mons in Belgium.

genera distinct from those established for the classification of tertiary and recent fish.

Chasm between the Eocene and Maestricht formations.—There appears, then, to be a greater chasm between the organic remains of the Eocene and Maestricht beds, than between the Eocene and Recent strata; for there are some living shells in the Eocene formations, while there are no Eocene fossils in the newest secondary group. It is not improbable that a greater interval of time may be indicated by this greater dissimilarity in fossil remains. In the 3rd and 4th chapters we endeavoured to point out that we have no right to expect, even when we have investigated a greater extent of the earth's surface, that we shall be able to bring to light an unbroken chronological series of monuments from the remotest eras to the present; but as we have already discovered a long succession of deposits of different ages, between the tertiary groups first known and the *recent* formations, so we may, perhaps, hereafter detect an equal, or even greater series, intermediate between the Maestricht beds and the Eocene strata.

Duration of secondary periods.—The different subdivisions of the secondary group No. 1, extending from the chalk of Maestricht to the lower green-sand inclusive, may, perhaps, relate to a lapse of ages as immense as the united tertiary periods, of which we have sketched the eventful history in this volume. Such a conjecture, at least, seems warranted, if we can form any estimate of the quantity of time, by comparing the amount of vicissitude in animal life which has occurred during its lapse.

Position of former continents.—The existence of sea as well as land, at every geological period, is attested by the remains of terrestrial plants imbedded in the deposits of all ages, even the most remote. We find fluviatile shells not unfrequently in the secondary strata, and here and there some fresh-water formations; but the latter are less common than in the tertiary series. For this fact we have prepared the reader's mind, by the views advanced in the third chapter

respecting the different circumstances under which we conceive the secondary and tertiary strata to have originated. We have there hinted, that the former may have been accumulated in an ocean like the Pacific, where coralline and shelly limestone are forming, or in a basin like the bed of the western Atlantic, which may have received for ages the turbid waters of great rivers, such as the Amazon, and Orinoco, each draining a considerable extent of continent. The *tertiary* deposits, on the other hand, may have been accumulated during the growth of a continent, by the successive emergence of new lands, and the uniting together of islands. During such changes, inland seas and lakes would be caused, and afterwards filled up with sediment, and then raised above the level of the waters.

That the greater part of the space now occupied by the European continent was sea when some of the secondary rocks were produced, must be inferred from the wide areas over which several of the marine groups are diffused; but we do not suppose that the quantity of land was less in those remote ages, but merely that its position was very different. In the above tabular view of the secondary rocks, we have shown that immediately below the division No. 1, or 'the chalk and green-sand,' is placed a fresh-water formation called, in the south-east of England, the Wealden. This group has been ascertained to extend from west to east (from Lulworth Cove to the boundary of the Lower Boulonnois) about 200 English miles, and from north-west to south-east (from Whitchurch to Beauvais), about 220 miles, the depth or total thickness of the beds, where greatest, being about 2000 feet *.

Now these phenomena most clearly indicate, that there was a constant supply in this region, for a long period, of a considerable body of fresh water, such as might be supposed to have drained a continent, or a large island, containing within it a lofty chain of mountains. Dr. Fitton, in speaking of these appearances, recalls to our recollection that the delta of the newly-discovered Quorra, or Niger, in Africa, stretches into the interior

* Fitton's Geology of Hastings, p. 58.

for more than 170 miles, and occupies, it is supposed, a space of more than 300 miles along the coast, thus forming a surface of more than 25,000 square miles, or equal to about one half of England *.

Now if this modern 'delta,' or, in other words, that part of the bed of the Atlantic which has been converted into land by matter deposited immediately at the river's mouth, be so extensive, how much larger may be the space over which the same kind of sediment may be distributed by the action of the tides and currents! If, then, groups like the Wealden may be formed near the mouths of great rivers, others, like the lias, may be produced by the wider dispersion of similar materials over larger submarine areas. For we may conceive that the Niger may carry out the remains of land plants, and the carcasses and bones of fluviatile reptiles, into places where they may be swept away by currents and afterwards mingled far and wide with the marine shells and corals of the Atlantic.

The reader will remember that we stated, in the first volume†, that the common crocodile of the Ganges frequents both fresh and salt water, the same species being sometimes seen far inland, many hundred miles from the sea, and at the same time swarming on the sand-banks in the salt and brackish water beyond the limits of the delta.

If we are asked where the continent was placed from the ruins of which the Wealden strata were derived, we are almost tempted to speculate on the former existence of the Atlantis of Plato, which may be true in geology, although fabulous as an historical event. We know that the present European lands have come into existence almost entirely since the deposition of the chalk, and the same period may have sufficed for the disappearance of a continent of equal magnitude, situated farther to the west.

Secondary fresh-water deposits why rare.—If there were extensive tracts of land in the secondary period, we may presume that there were lakes also; yet we are not aware of any

* Fitton's Geology of Hastings, p. 58, who cites Lander's Travels.

† Page 243; Second Edition, p. 279.

pure lacustrine formations interstratified with rocks older than the chalk. Perhaps their absence may be accounted for by the adoption of the theoretical views above set forth; for if the present ocean coincides for the most part with the site of the ancient continent, the places occupied by lakes must have been submerged. It should also be recollected, that the area covered by lakes, at any one time, is very insignificant in proportion to the sea, and, therefore, we may expect that, after the earth's surface has undergone considerable revolutions in its physical geography, the lacustrine strata will be concealed, for the most part, under superimposed marine deposits.

Persistency of mineral character.—In the same manner as it is rare and difficult to find ancient lacustrine strata, so also we can scarcely expect to discover newer marine groups preserving the same lithological characters continuously throughout wide areas. The chalk now seen stretching for thousands of miles over different parts of Europe, has become visible to us by the effect, not of one, but of many distinct series of movements. Time has been required, and a succession of geological periods, to raise it above the waves in so many regions; and if calcareous rocks of the Eocene or Miocene periods have been formed, preserving an homogeneous mineral composition throughout equally extensive regions, it may require convulsions as numerous as all those which have occurred since the origin of the chalk, to bring them up within the sphere of human observation. Hence the rocks of more modern periods may appear of partial extent, as compared to those of remoter eras, not because there was any original difference of circumstances throughout the globe when they were formed, but because there has not been sufficient time for the development of a great series of subterranean volcanic operations since their origin.

At the same time, the reader should be warned not to place implicit reliance on the alleged persistency of the same mineral characters in secondary rocks *. When it was first ascertained that an order of succession could be traced in the principal

* See some remarks on this subject, vol. i. p. 90, and Second Edition, p. 102.

groups of strata above enumerated by us, names were given to each, derived from the mineral composition of the rocks in those parts of Germany, England or France, where they happened to be first studied. When it was afterwards acknowledged that the zoological and phytological characters of the same formations were far more persistent than their mineral peculiarities, the old names were still retained, instead of being exchanged for others founded on more constant and essential characters. The student was given to understand, that the terms chalk, green-sand, oolite, red marl, coal, and others, were to be taken in a liberal and extended sense; that chalk was not always a cretaceous rock, but, in some places, as on the northern flanks of the Pyrenees, and in Catalonia, a saliferous red marl. Green-sand, it was said, was rarely green, and frequently not arenaceous, but represented in parts of the south of Europe by a hard dolomitic limestone. In like manner, it was declared that the oolitic texture was rather an exception to the general rule in rocks of the oolitic period, and that no particle of carbonaceous matter could often be detected in the true *coal* formation of many districts where it attains great thickness. It must be obvious to every one, that inconvenience and erroneous prepossessions could hardly fail to arise from such a nomenclature, and accordingly a fallacious mode of reasoning has been widely propagated, chiefly by the influence of a language so singularly inappropriate.

After the admission that the identity or discordance of mineral character was by no means a sure test of agreement or disagreement in the age of rocks, it was still thought, by many geologists, that if they found a rock at the antipodes agreeing precisely in mineral composition with another well known in Europe, they could fairly presume that both are of the same age, *until the contrary could be shown.*

Now it is usually difficult or impossible to combat such an assumption, on geological grounds, so long as we are imperfectly acquainted with the geology of a distant country, inasmuch as there are often no organic remains in the foreign

stratum, and even if these abound and are specifically different from the fossils of the supposed European equivalent, it may be objected, that we cannot expect the same species to have inhabited very distant quarters of the globe at the same time.

Supposed universality of red marl.—We shall select a remarkable example of the erroneous mode of generalizing now alluded to. A group of red marl and sandstone, sometimes containing salt and gypsum, is found in England interposed between the lias and the carboniferous strata. For this reason, other red marls and sandstones, associated some of them with salt and others with gypsum, and occurring not only in different parts of Europe, but in Peru, India, the salt deserts of Asia, those of Africa, in a word, in every quarter of the globe, have been referred to one and the same period. The burden of proof is not supposed to rest with those who insist on the identity of age of all these groups, so that it is in vain to urge as an objection, the improbability of the hypothesis which would imply that all the moving waters on the globe were once simultaneously charged with sediment of a red colour.

But the absurdity of pretending to identify, in age, all the red sandstones and marls in question, has at length been sufficiently exposed, by the discovery that, even in Europe, they belong decidedly to many different epochs. We have already ascertained, that the red sandstone and red marl with which the rock-salt of Cardona is associated, may be referred to the period of our chalk and green-sand *. We have pointed out that in Auvergne there are red marls and variegated sandstones, which are undistinguishable in mineral composition, from the new red sandstone of English geologists, but which were deposited in the Eocene period; and, lastly, the gypseous red marl of Aix in Provence, formerly supposed to be a marine secondary group, is now acknowledged to be a tertiary freshwater formation.

* I was led to this opinion when I visited Cardona in 1830, and before I was aware that M. Dufrénoy had arrived at the same conclusions. Ann. des Sci. Nat., Avril, 1831, p. 449.

Secondary rocks why more consolidated.—One of the points where the analogy between the secondary and tertiary formations has been supposed to fail is the greater degree of solidity observable in the former. Undoubtedly the older rocks, in general, are more stony than the newer; and most of the tertiary strata are more loose and incoherent in their texture than the secondary. Many exceptions, however, may be pointed out, especially in those calcareous and siliceous deposits which have been precipitated in great part from the waters of mineral springs, and have been originally compact. Of this description are a large proportion of the Parisian Eocene rocks, which are more stony than most of the English secondary groups.

But a great number of strata have evidently been consolidated *subsequently to their deposition* by a slow lapidifying process. Thus loose sand and gravel are bound together by waters holding carbonate and oxide of iron, carbonate of lime, silica, and other ingredients, in solution. These waters percolate slowly the earth's crust in different regions, and often remove gradually the component elements of fossil organic bodies, substituting other substances in their place. It seems, moreover, that the draining off of the waters during the elevation of land may often cause the *setting* of particular mixtures, in the same manner as mortar hardens when desiccated, or as the recent soft marl of Lake Superior becomes highly indurated when exposed to the air *. The conversion of clay into shale, and of sand into sandstone, may, in many cases, be attributed to simple pressure, produced by the weight of superincumbent strata, or by the upward heaving of subjacent masses during earthquakes. Heat is another cause of a more compact and crystalline texture, which will be considered when we speak of the strata termed 'primary.' All the changes produced by these various means require *time* for their completion; and this may explain, in a satisfactory manner, why the older rocks are most consolidated, without

* Vol. i. p. 226, and Second Edition, p. 259.

entitling us to resort to any hypothesis respecting an *original* distinctness in the degree of lapidification of the secondary strata.

Secondary rocks why more disturbed.—As the older formations are generally more stony, so also they are more fractured, curved, elevated, and displaced, than the newer. Are we, then, to infer, with some geologists, that the disturbing forces were more energetic in remoter ages? No conclusion can be more unsound; for as the moving power acts from below, the newer strata cannot be deranged without the subjacent rocks participating in the movement; while we have evidence that the older have been frequently shattered, raised, and depressed, again and again, before the newer rocks were formed. It is evident that if the disturbing power of the subterranean causes be exerted with *uniform* intensity in each succeeding period, the quantity of convulsion undergone by different groups of strata will generally be great in proportion to their antiquity. But exceptions will occur, owing to the partial operation of the volcanic forces at particular periods, so that we sometimes find tertiary strata more elevated and disturbed, in particular countries, than are the secondary rocks in others.

Some of the enormous faults and complicated dislocations of the ancient strata may probably have arisen from the continued repetition of earthquakes in the same place, and sometimes from two distinct series of convulsions, which have forced the same masses in different, and even opposite directions, sometimes by vertical, at others by horizontal movements.

Secondary volcanic rocks of different ages.—The association of volcanic rocks with different secondary strata is such as to prove, that there were igneous eruptions at many distinct periods, as also that they were confined during each epoch, as now, to limited areas. Thus, for example, igneous rocks contemporaneous with the carboniferous strata abound in some countries, but are wanting in others. So it is evident that the bottom of the sea, on which the oolite and its contemporary deposits were thrown down, was, for the most part, free from

submarine eruptions; but at some points, as in the Hebrides, it seems that the same ocean was the theatre of volcanic action. We have mentioned in the first volume *, that as the ancient eruptions occurred in succession, sufficient time usually intervening between them to allow of the accumulation of many subaqueous strata, so also should we infer that subterranean movements, which are another portion of the volcanic phenomena, occurred separately and in succession.

* Chap. v. p. 88; and Second Edition, p. 100.

CHAPTER XXIV.

On the relative antiquity of different mountain-chains—Theory of M. Elie de Beaumont—His opinions controverted—His method of proving that different chains were raised at distinct periods—His proof that others were contemporaneous—His reasoning, why not conclusive—His doctrine of the parallelism of contemporaneous lines of elevation—Objections—Theory of parallelism at variance with geological phenomena as exhibited in Great Britain—Objections of Mr. Conybeare—How far anticlinal lines formed at the same period are parallel—Difficulties in the way of determining the relative age of mountains.

RELATIVE ANTIQUITY OF MOUNTAIN-CHAINS.

THAT the different parts of our continents have been elevated, in succession, to their present height above the level of the sea, is an opinion which has been gradually gaining ground with the progress of science; but no one before M. Elie de Beaumont had the merit even of attempting to collect together the recorded facts which bear on this subject, and to reduce them to one systematic whole. The above-mentioned geologist was eminently qualified for the task, as one who had laboured industriously in the field of original observation, and who combined a considerable knowledge of facts with an ardent love of generalization.

But he has been ambitious, we think unfortunately, of anticipating the march of discovery in reference to the comparative antiquity of different mountain-chains and their supposed connexion with changes in the animate world. His speculations differ entirely from the conclusions to which we have arrived, and we therefore think it necessary to explain fully the reasons of our dissent. In order to put the reader in possession of the principal points of M. de Beaumont's theory, we shall first offer a brief sketch of them, and then proceed to analyze the data on which they are founded.

Theory of M. Elie de Beaumont.

1st. He supposes 'that in the history of the earth there have been long periods of comparative repose, during which the deposition of sedimentary matter has gone on in regular continuity, and there have also been short periods of paroxysmal violence during which that continuity was broken.

'2ndly. At each of these periods of violence or "revolution" in the state of the earth's surface, a great number of mountain-chains have been formed suddenly.

'3rdly. All the chains thrown up by a particular revolution have one uniform direction, being parallel to each other within a few degrees of the compass, even when situated in remote regions; but the chains thrown up at different periods have, for the most part, different directions.

'4thly. Each "revolution," or, as it is sometimes termed, "frightful convulsion," has coincided in date with another geological phenomenon, namely, "the passage from one independent sedimentary formation to another," characterized by a considerable difference in "organic types."

'5thly. There has been a recurrence of these paroxysmal movements from the remotest geological periods, and they may still be reproduced, and the repose in which we live may hereafter be broken by the sudden upthrow of another system of parallel chains of mountains.

'6thly. We may presume that one of these revolutions has occurred within the historical era when the Andes were upheaved to their present height, for that chain is the best defined and least obliterated feature observable in the present exterior configuration of the globe, and was probably the last elevated.

'7thly. The instantaneous upheaving of great mountain masses must cause a violent agitation in the waters of the sea, and the rise of the Andes may, perhaps, have produced that transient deluge which is noticed among the traditions of so many nations.

'Lastly. The successive revolutions above mentioned cannot

be referred to ordinary volcanic forces, but may depend on the secular refrigeration of the heated interior of our planet*.'

It will at once be seen, that the greater number of the above propositions are directly opposed to that theory which we have endeavoured to deduce, partly from the study of the earth's structure, and partly from the analogy of changes now in progress in the animate and inanimate world.

Our opinions respecting the alternation of periods of general repose and disorder have been explained in former chapters †; and we have pointed out our objections to the hypothesis which substitutes paroxysmal violence for the reiterated recurrence of minor convulsions ‡.

The speculation of M. de Beaumont concerning the 'secular refrigeration' of the internal nucleus of the globe, considered as a cause of the instantaneous rise of mountain-chains, appears to us mysterious in the extreme, and not founded upon any induction from facts; whereas the intermittent action of subterranean volcanic heat is a known cause capable of giving rise to the elevation and subsidence of the earth's crust without interruption to the *general* repose of the habitable surface.

We have shown, in the second volume, that we believe the changes in physical geography, which are unceasingly in progress, to be among the causes which contribute, in the course of ages, to the extermination of certain species of animals and plants; but the influence of these causes is slow and, for the most part, indirect, and has no analogy with those sudden catastrophes which are introduced into the theory now under review. What have appeared to us to be the true causes of the abrupt transitions from one set of strata to another, containing distinct organic remains, have been explained at length in the third and fourth chapters of this volume §.

* Ann. des Sci. Nat., Septembre, Novembre, et Décembre, 1829. Revue Française, No. 15, May, 1830. The last version by M. de B. which I have seen is in the Phil. Mag. and Annals, No. 58, new series, p. 241.

† Vol. i. pp. 64 and 88, and Second Edition, pp. 73 and 100; vol. ii. p. 196, and Second Edition, p. 203.

‡ Vol. i. p. 79, and Second Edition, p. 90.

§ See particularly from p. 26 to p. 34.

The notion of deluges accompanying the protrusion of mountain-chains is founded on a belief of the instantaneousness of the movement which we are prepared to controvert, and on other assumptions which we have discussed in a former part of this volume *. On these topics, therefore, it will be unnecessary for us to dilate at present, and we shall merely address ourselves to the analysis of that evidence whereby M. de Beaumont endeavours to establish the successive elevation of different mountain-chains, and the supposed law of parallelism in the lines of contemporaneous elevation.

M. de Beaumont's proofs that different chains were raised at different epochs.—'We observe,' says M. Elie de Beaumont, 'along nearly all mountain-chains, when we attentively examine them, that the most recent rocks extend horizontally up to the foot of such chains, as we should expect would be the case if they were deposited in seas or lakes of which these mountains have partly formed the shores; whilst the other sedimentary beds tilted up, and more or less contorted on the flanks of the mountains, rise in certain points even to their highest crests †.' There are, therefore, in each chain two classes of sedimentary rocks, the ancient or inclined beds, and the newer or horizontal. It is evident that the first appearance of the chain itself was an event 'intermediate between the period when the beds, now upraised, were deposited, and that when the strata were produced horizontally at its feet.'

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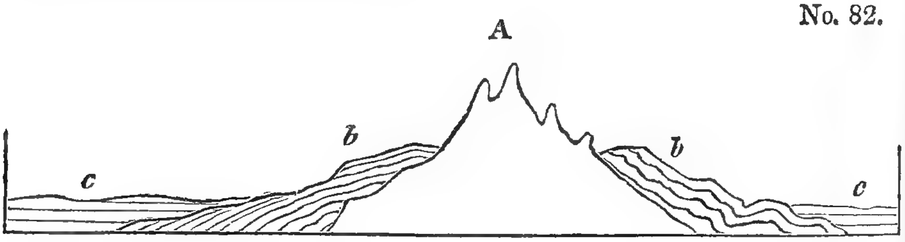

Thus the chain A received its present form after the deposition of the strata *b*, which have undergone great movements, and before the deposition of the group *c*, in which the strata have not suffered derangement.

* See above, p. 148.

† Phil. Mag. and Annals, No. 58, new series, p. 242.

If we then discover another chain, B, in which we find not only the formation *b*, but the group *c* also, disturbed and

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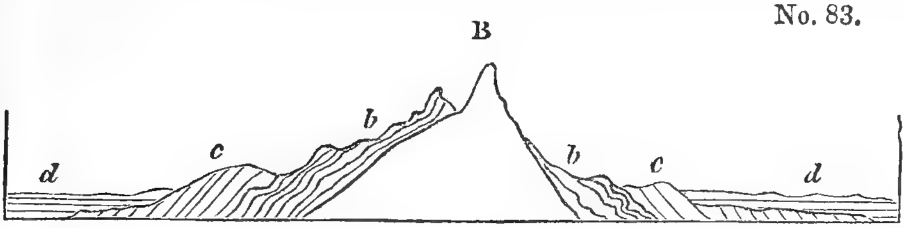

thrown on its edges, we may infer that the latter chain is of subsequent date to A; for B was elevated *after* the deposition of *c*, and before that of the group *d*; whereas A originated *before* the strata *c* were formed.

In order to ascertain whether other mountain ranges are of contemporaneous date with A and B, or whether they are referrible to *distinct* periods, we have only to inquire whether the geological phenomena are identical, namely, whether the inclined and undisturbed sets of strata correspond to those in the types above mentioned.

Objections to M. de Beaumont's theory.—Now all this reasoning is perfectly correct, so long as the particular groups of strata *b* and *c* are not confounded with the geological periods to which they may belong, and provided due latitude is given to the term contemporaneous; for it should be understood to allude not to a moment of time, but to the interval, whether brief or protracted, which has elapsed between two events, namely, between the accumulation of the inclined and that of the horizontal strata.

But, unfortunately, the distinct import of the terms 'formation' and 'period' has been overlooked, or not attended to by M. de Beaumont, and hence the greater part of his proofs are equivocal, and his inferences uncertain; and even if no errors had arisen from this source, the length of some of his intervals is so immense, that to affirm that all the chains raised in such intervals were *contemporaneous*, is an abuse of language.

In order to illustrate our argument, let us select the Pyrenees as an example. This range of mountains, says M. de Beaumont, rose suddenly (à un seul jet) to its present

elevation at a certain epoch in the earth's history, namely, between the deposition of the chalk and that of the tertiary formations; for the former are seen in vertical, curved, and distorted beds on the flanks of the chain, while the latter rest upon them in horizontal strata at its base.

The only proof offered of the extreme suddenness of the convulsion is the shortness of the time which intervened between the formation of the chalk and that of the tertiary strata. 'For it follows,' we are told, 'from the unconformable position of two systems of beds, the inclined and the horizontal, that the elevation of the former has not been effected in a continuous and progressive manner, but that it has been produced in a space of time comprised between the periods of deposition of the two consecutive rocks, and during which no regular series of beds was formed; in a word, that it was sudden and of short duration *.'

We are prepared to show that the Pyrenees cannot be assumed to have risen, as M. de Beaumont imagines, in the interval between the period of the chalk and that of the tertiary strata; for we can only say that the movement took place after the commencement of the chalk epoch, and before the close of the Miocene tertiary period. But, first, let us suppose the premises of our author to be correct, and let us permit him to exclude the whole period of the chalk, on one hand, and of the tertiary formations in contact with it on the other; what will then be the duration of the interval? We can only estimate its importance by ascertaining what description of chalk is found on the flanks of the Pyrenees, and what horizontal tertiary formations at their base.

Now the beds called chalk, although they differ widely in mineral composition from the white chalk with flints of England and France, contain the same species of fossil shells, and may, therefore, on that evidence, be referred to the same age †. On the other hand, the horizontal tertiary strata at the

* Phil. Mag. and Annals, No. 58, new series, p. 243.

† The fossils which I collected in company with Captain S. E. Cook, R. N.,

western end of the Pyrenees, near Bayonne, are certainly of the Miocene period.

Such, then, being the age of the strata, and granting even that the movement occurred after the period of the white chalk, and before the beginning of the Miocene era, there still remains ample scope for conjecture as to the date of the event. For the upheaving of the Pyrenees may have been going on when the animals of the Maestricht beds flourished, or during the indefinite ages which may have elapsed between their extinction and the introduction of the Eocene tribes, or during the Eocene epoch, or between that and the Miocene. Or the rise may have been going on continuously throughout several or all of these periods.

But this is not all; we must include within the possible space of time wherein the convulsions may have happened, part of the epochs both of the chalk and of the Miocene species. We have stated, that the newer Pliocene beds in Sicily have been raised during the newer Pliocene epoch, partly, perhaps, in the Recent, but this latter supposition will lend equal support to our present argument. Now, it is evident that the greater part of the species of testacea which pre-existed in the Mediterranean have survived the elevation of the newer Pliocene beds in Sicily, and in the same manner there is no reason to conclude that the rise of the chalk in the Pyrenees exterminated the animals which lived in the sea wherein the chalk was formed. In that case, a series of convulsions may not only have begun, but may even have been completed before the era when the Maestricht beds originated.

In like manner the sea may have been inhabited by Miocene testacea for ages before the deposition of those particular Miocene strata which occur at the foot of the Pyrenees, and the disturbing forces may have operated in the Miocene period,

from the newest secondary beds on the flanks of the Pyrenees, near Bayonne, were examined by M. Deshayes, and found identical with species of the chalk near Paris.

notwithstanding the horizontality of the tertiary formations of that age.

In order to illustrate the grave objections above advanced, which are aimed at the validity of the whole of de Beaumont's reasoning, let the reader suppose, that in some country three styles of architecture had prevailed in succession, each for a period of 1000 years; first the Greek, then the Roman, and then the Gothic; and that a tremendous earthquake was known to have occurred in the same district during some part of the three periods,—a shock of such violence as to have levelled to the ground every building. If an antiquary, desirous of discovering the date of the catastrophe, should first arrive at a city where several Greek temples were lying in ruins and half engulphed in the earth, while many Gothic edifices were standing uninjured, could he determine on these data the era of the shock? Certainly not. He could merely affirm that it happened at some period after the introduction of the Greek style, and before the Gothic had fallen into disuse. Should he pretend to define the date of the convulsion with greater precision, and decide that the earthquake must have occurred in the interval between the Greek and Gothic periods, that is to say, when the Roman style was in use, the fallacy in his reasoning would be too palpable to escape detection for a moment.

Yet such is the nature of the erroneous induction which we are now exposing. For, in the example above proposed, the erection of a particular edifice is not more distinct from the period of architecture in which it may have been raised, than is the deposition of chalk, or any other set of strata, from the geological epoch to which they may belong. Yet, if on these grounds we are compelled to include in the interval in which the elevation of each chain may have happened, the periods of those two classes of formations before alluded to, the deranged and the horizontal, it follows that, even if all the facts appealed to by de Beaumont are correct, his intervals are of indefinite extent. He is not even warranted in asserting that the chain

A (p. 340) is older than B (p. 341), if he means that it was elevated at a different *geological period*, for both may have been upheaved during the same period, namely, that when the strata *c* were formed.

Supposed parallelism of contemporaneous lines of elevation.— So, also, when he infers that two chains were simultaneously upraised, the proof fails, since the close of the period of the disturbed strata and the commencement of the era of the undisturbed must be added to the lapse of time during which the two chains may have originated, and in separate parts of which each may have been produced. With the insufficiency of the above evidence the whole force of the argument in support of the parallelism of lines of contemporaneous movement is annihilated.

This hypothesis, indeed, of parallelism appears, even as stated by the author, in some degree at variance with itself. When certain European chains had been assumed to have been raised at the same time on the data already impugned, it was found that several of these contemporaneous chains had a parallel direction. Hence it was presumed to be a general law in geological dynamics that the chains upheaved at the same time are parallel. For example, it was said that the Pyrenees and other coetaneous chains, such as the northern Apennines, have a direction about W. N. W. and E. S. E., and to this line the Alleghanies in North America conform, as also the ghauts of Malabar, and certain chains in Egypt, Syria, northern Africa, and other countries; and from this mere conformity in direction it was presumed that all these mountain-ranges were thrown up simultaneously.

To select another example, the principal chain of the Alps, differing in age and direction from the Pyrenees, is parallel to the Sierra Morena, the Balkan, the chain of Mount Atlas, the central chain of the Caucasus, and the Himalaya. All these ridges, therefore, were probably heaved up by the same paroxysmal convulsion! The western Alps, on the other hand, rose at a still earlier period, when the parallel chains of Kiöl, in Scan-

dinavia, certain chains in Morocco, and the littoral Cordillera of Brazil, were formed!

Not only do these speculations refer to mountains never touched, as M. Boué remarks, by the hammer of the geologist, but they proceed on the supposition, that in these distant chains the geological and geographical axes always coincide. Now we know that in Europe the *strike* * of the beds is not always parallel to the direction of the chain. As an exception, we may instance that pointed out by Von Dechen †, who states that in the Hartz the direction or *strike* of the strata of slate and greywacke is sometimes from E. and W. and frequently N. E. and S. W.; whereas the geographical direction of the mountain-chain is decidedly from E. S. E. to W. N. W.

In addition to these uncertainties, which should, in the present state of science, have deterred a geologist even from speculating on the phenomena of unexplored regions, the important admission is made by M. de Beaumont himself, that the elevating forces, whose activity must be referred to *different* epochs, have sometimes acted in Europe in *parallel* lines. 'It is worthy of remark, says that author, that the directions of three systems of mountains, namely, first, that of the Pilas and the Côte d'Or; secondly, that of the Pyrenees; and thirdly, that of the islands of Corsica and Sardinia, are respectively parallel to three other systems, namely, first, that of Westmoreland and the Hunsdruck, secondly, that of the Ballons (or Vosges) and the hills of the Bocage, in Calvados; and thirdly, the system of the north of England. The corresponding directions only differ in a few degrees, and the two series have succeeded each other in the same order, leading to the supposition, that there has been *a kind of periodical*

* The term 'strike' has been recently adopted by some of our most eminent geologists from the German 'streich,' to signify what our miners call the 'line of bearing' of the strata. Such a term was much wanted, and as we often speak of *striking off* in a given direction, the expression seems sufficiently consistent with analogy in our language.

† Trans. of De la Beche's Geol. Manual, p. 41.

recurrence of the same, or nearly the same, directions of elevation *.'

Here then we have three systems of mountains, A, B, C, which were formed at successive epochs, and have each a different direction; and we have three other systems, D, E, F, which, although they are assumed to have the same strike, as the series first mentioned (D corresponding with A, E with B, and F with C), are nevertheless declared to have been formed at different periods. On what principle, then, is the age of an Indian or transatlantic chain referred to one of these European lines rather than another? why is the age of the Alleghanies, or the ghauts of Malabar, determined by their parallelism to B rather than to E, to the Pyrenees rather than to the Ballons of the Vosges?

The substance of the last objection has been anticipated by M. Boué †, who, at the same time, disputes the accuracy of many of the *facts* appealed to by M. de Beaumont. Other errors in fact have also been pointed out by MM. Keferstein, Von Dechen, and De la Beche ‡. But the incorrectness of some of these data might not have affected the validity of the general theory if it had been founded on a solid basis. In regard to the Alps, MM. Necker and Studer have informed me, that on re-examining that chain since de Beaumont's memoirs were published, they have been unable to reconcile the phenomena there exhibited with his views relating to the strike and dip of that great chain.

Professor Sedgwick has declared his adhesion to the opinions of de Beaumont; but we are not aware that he had maturely considered them in all their bearings; and he has stated some important objections to the doctrine of 'parallelism §.' Among others, he has remarked, that in consequence of the spheroidal figure of the earth, different mountain-chains, running north and

* Phil. Mag. and Annals, No. 58, new series, pp. 255, 256.

† Journ. de Géologie, tome iii. p. 338.

‡ Geol. Manual, p. 501, and Second Edition, p. 519.

§ Anniv. Address to the Geol. Soc., Feb., 1831.

south, cannot be strictly said to be parallel, since they would, if prolonged, cross each other at the poles.

Objections of Mr. Conybeare.—An inquiry was proposed, in 1831, by the British Association for the Promotion of Science, 'whether the theory of M. Elie de Beaumont, concerning the parallelism of lines of elevation of the same geological era, is agreeable to the phenomena as exhibited in Great Britain?' Mr. Conybeare, in the first part of his report, in answer to this inquiry *, points out many lines of *distinct* ages in England which are exactly *parallel*, and others which, according to the rules laid down by M. de Beaumont, ought to agree in age with certain continental chains, and yet do not, having an entirely *different* direction. He imagines that the general strike of the secondary strata of our island, from N. E. to S. W., has been the result, not of any violent or single convulsion, but, on the contrary, of 'a gradual, gentle, and protracted upheaving, continued without interruption *during the whole period of the formation of all these strata.*'

The same author has also adverted to some of the difficulties attending the exact determination of the geological epochs of the elevation of each chain, especially where the disturbed and undisturbed strata in contact are not very nearly of the same age, or, as he expresses it, 'where they are not terms immediately following one another in the regular geological series †.' We were forcibly struck with the uncertainty arising from this cause during a late tour, when we discovered that at the eastern end of the Pyrenees, on the side of France, tertiary strata of the older Pliocene epoch abut against vertical mica-schist; while at the western extremity of the same mountain-range we find the disturbed series to consist of chalk, the undisturbed of Miocene strata. The chain is then lost in the sea, and we are precluded from pushing our investigations farther to the westward; but

* Phil. Mag. and Journ. of Sci., No. 2, third series, p. 118. The second part, I believe, is not yet published.

† Ibid., p. 120.

if we could follow the strike of the beds in their submarine prolongation, who shall say that the *tilted* group might not be found to include strata newer than the chalk, the *horizontal* beds older than the Miocene?

Supposed instantaneous rise of a mountain-chain.—'Everything shows, says M. Élie de Beaumont, that the *instantaneous* elevation of the beds of a whole mountain-chain is an event of a different order from those which we *daily* witness *.'

We observe with pleasure the rejection, by Mr. Conybeare, of the hypothesis that the disturbances affecting large geographical districts have been produced *at one blow*, rather than by a series of shocks which may have occurred at intervals through a long period of ages, and that he contends for the greater probability of successive convulsions, on the ground that such an hypothesis is most conformable to the only analogy presented by actual causes—'the operations of volcanic forces †.'

Modern volcanic lines not parallel.—By that analogy we are led to suppose that the lines of convulsion, at former epochs, were far from being uniform in direction, for the trains of *active* volcanos are not parallel, as every one is aware who has studied Von Buch's masterly survey of the general range of volcanic lines over the globe ‡, and the elevations and subsidences caused by modern earthquakes, although they may sometimes run in parallel lines within limited districts, have not been observed to have a common direction in distant and independent theatres of volcanic action.

We do not doubt that in many regions the ridges, troughs, and fissures caused by modern earthquakes, are, to a certain extent, parallel to each other, but only within a limited range of country; and such appears to have been the case in many districts at former eras. The anticlinal lines of the Weald Valley, before alluded to, and of the Isle of Wight, may, in this manner, have been contemporaneous, that is to say, both

* Phil. Mag. and Annals, No. 58, new series, p. 243.

† Phil. Mag. and Journ. of Sci., No. 2, third series, p. 121.

‡ Physical. Besch. der Canarischen Inseln. Berlin, 1825.

may have been formed in some part of the Eocene period,—an hypothesis which does not involve the theory of their having been due to paroxysmal convulsions during one part of that vast period.

It should be observed, that as some trains of burning volcanos are parallel to each other, so at all periods some independent lines of elevation may be parallel *accidentally*, or not in obedience to any known law of parallelism; but, on the contrary, as exceptions to the general rule. We hope that the speculations of M. de Beaumont will be useful in inducing geologists to inquire how far the uniformity in the direction of the beds, in a region which has been agitated at any particular period, may extend; but we trust that travellers will not be led away with the idea that, on arriving in India, America, or New Holland, they have only to use the compass and examine the strike of the beds in order to discover the relative era of the movement by which they were upraised. Such problems can in truth be only solved by a patient and laborious investigation of the sedimentary formations occurring in each region, and especially by the study of their organic remains.

Difficulties attending the determination of the relative age of mountains.—If we are asked whether we cherish no expectation of fixing a chronological succession of epochs of elevation of different mountain-chains, we reply, that in the present state of our science we have no hope of making more than a loose approximation to such a result. The difficulty depends chiefly on the broken and interrupted nature of the series of sedimentary formations hitherto brought to light, which appears so imperfect that we can rarely be sure that the memorials of some great interval of time are not wanting between two groups now classed as consecutive. Another great source of ambiguity arises from the small progress which we have yet made in identifying strata in countries somewhat distant from each other.

There may be instances where the same set of strata, preserving throughout a perfect identity of mineral character, may be traced continuously from the flanks of one independent

mountain-chain to the base of another, the beds being vertical or inclined in one chain, and horizontal in the other. We might then decide with confidence, according to the method proposed by M. de Beaumont, on the relative eras when these chains had undergone disturbance; and from one point thus securely established, we might proceed to another, until we had determined the dates of many neighbouring lines of convulsion.

We fear that the cases are rare where such evidence can be obtained; and, for the most part, we can identify the age of strata, not by their continuity and homogeneous mineral character, but by organic remains. When by their aid we prove strata to be contemporaneous, we must generally speak with great latitude, merely intending that they were deposited in the same geological epoch during which certain animals and plants flourished.

CHAPTER XXV.

On the rocks usually termed 'Primary'—Their relation to volcanic and sedimentary formations—The 'primary' class divisible into stratified and unstratified —Unstratified rocks called Plutonic—Granite veins—Their various forms and mineral composition—Proofs of their igneous origin—Granites of the same character produced at successive eras—Some of these newer than certain fossiliferous strata—Difficulty of determining the age of particular granites—Distinction between the volcanic and the plutonic rocks—Trappean rocks not separable from the volcanic—Passage from trap into granite—Theory of the origin of granite at every period from the earliest to the most recent.

ON THE ROCKS COMMONLY CALLED PRIMARY.

We shall now treat of the class of rocks usually termed 'primary,' a name which, as we shall afterwards show, is not always applicable, since the formations so designated sometimes belong to different epochs, and are not, in every case, more ancient than the secondary strata. In general, however, this division of rocks may justly be regarded as of higher antiquity than the oldest secondary groups before described, and they may, therefore, with propriety be spoken of in these concluding chapters, for we have hitherto proceeded in our retrospective survey of geological monuments from the newer to those of more ancient date.

In order to explain to the reader the relation which we conceive the rocks termed 'primary' to bear to the tertiary and secondary formations, we shall resume that general view of the component parts of the earth's crust of which we gave a slight sketch in the preliminary division of our subject in the 2nd chapter *.

We there stated that sedimentary formations, containing organic remains, occupy a large part of the surface of our continents, but that here and there volcanic rocks occur, breaking through, alternating with, or covering the sedimentary deposits,

* See above, p. 8.

so that there are obviously two orders of mineral masses formed at the surface which have a distinct origin, the aqueous and the volcanic.

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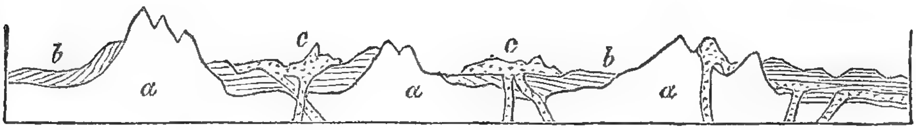

a, Formations called primary (stratified and unstratified).
b, Aqueous formations. *c*, Volcanic rocks.

Besides these, however, there is another class, which cannot be assimilated precisely to either of the preceding, and which is often seen underlying the sedimentary, or breaking up to the surface in the central parts of mountain-chains, constituting some of the highest lands, and, at the same time, passing down and forming the inferior parts of the crust of the earth. This class, usually termed 'primary,' is divisible into two groups, the stratified and the unstratified. The stratified consists of the rocks called gneiss, mica-schist, argillaceous-schist (or clay-slate), hornblende-schist, primary limestone, and some others. The unstratified, or Plutonic, is composed in great measure of granite, and rocks closely allied to granite. Both these groups agree in having, for the most part, a highly crystalline texture, and in not containing organic remains.

Plutonic rocks.—The unstratified crystalline rocks have been very commonly called Plutonic, from the opinion that they were formed by igneous action at great depths, whereas the volcanic, although they also have risen up from below, have cooled from a melted state upon or near to the surface. The theory conveyed by the name Plutonic is, we believe, correct. Granite, porphyry, and other rocks of the same family, often occur in large amorphous masses, from which small veins and dikes are sent off, which traverse the stratified rocks called 'primary,' precisely in the manner in which lava is seen in some places to penetrate the secondary strata.

Granite Veins.—We find also one set of granite veins intersecting another, and granitiform porphyries intruding

themselves into granite, in a manner analogous to that of the volcanic dikes of Etna and Vesuvius, where they cut and shift each other, or pass through alternating beds of lava and tuff.

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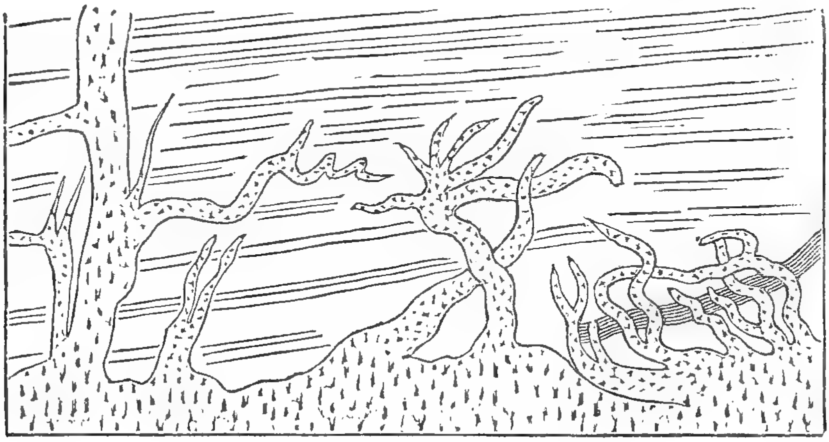

Granite veins traversing stratified rocks.

The annexed diagram will explain to the reader the manner in which these granite veins often branch off from the principal mass. Those on the right-hand side, and in the middle, are taken from Dr. Macculloch's representation of veins passing through the gneiss at Cape Wrath, in Scotland *. The veins on the left are described, by Captain Basil Hall, as traversing the argillaceous schist of the Table-Mountain at the Cape of Good Hope †.

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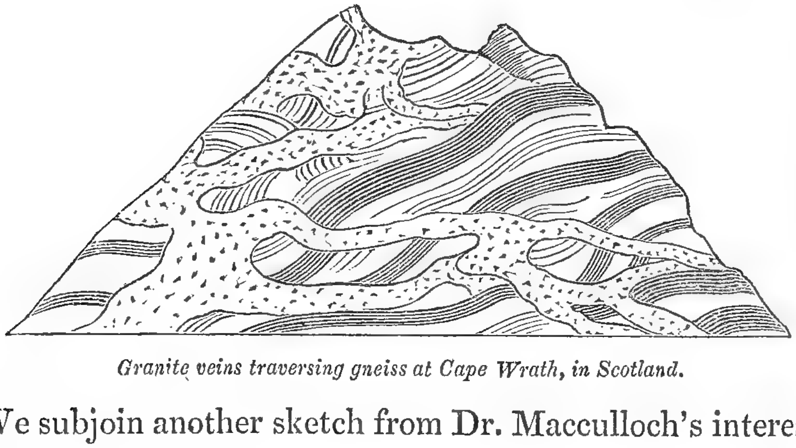

Granite veins traversing gneiss at Cape Wrath, in Scotland.

We subjoin another sketch from Dr. Macculloch's interesting

* Western Islands, plate 31.

† Account of the structure of the Table-Mountain, &c., Trans. Roy. Soc. Edin., vol. vii.

representations of the granite veins in Scotland, in which the contrast of colour between the vein and some of the dark varieties of hornblende-schist associated with the gneiss renders the phenomena more conspicuous.

The following sketch of a group of granite veins in Cornwall is given by Messieurs Von Oeynhausen and Von Dechen*.

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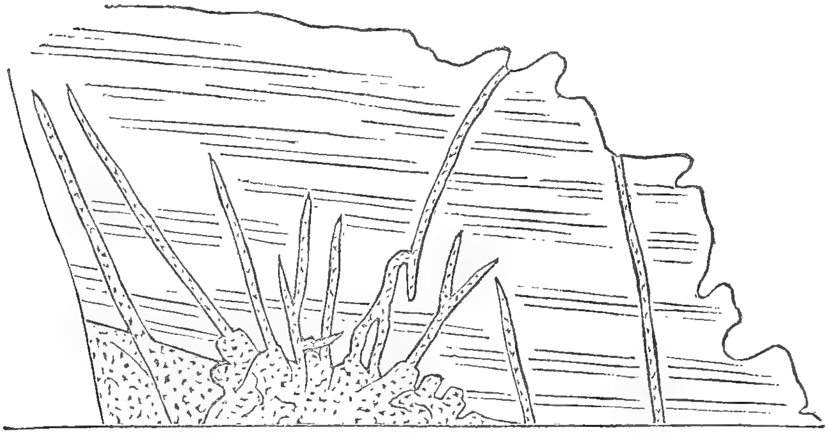

Granite veins passing through Hornblende slate, Carnsilver Cove, Cornwall.

The main body of the granite here is of a porphyritic appearance with large crystals of felspar; but in the veins it is fine-grained and without these large crystals. The general height of the veins is from 16 to 20 feet, but some are much higher.

The vein-granite of Cornwall very generally assumes a finer grain, and frequently undergoes a change in mineral composition, as is very commonly observed in other countries. Thus, according to Professor Sedgwick, the main body of the Cornish granite is an aggregate of mica, quartz, and felspar; but the veins are sometimes without mica, being a granular aggregate of quartz and felspar. In other varieties quartz prevails to the almost entire exclusion both of felspar and mica; in others, the mica and quartz both disappear, and the vein is simply composed of white granular felspar †.

Changes are sometimes caused in the intersected strata very

* Phil. Mag. and Annals, No. 27, new Series, March, 1829.

† On Geol. of Cornwall. Trans. of Cambridge Soc., vol. i. p. 124.

analogous to those which the contact of a fused mass might be supposed to produce.

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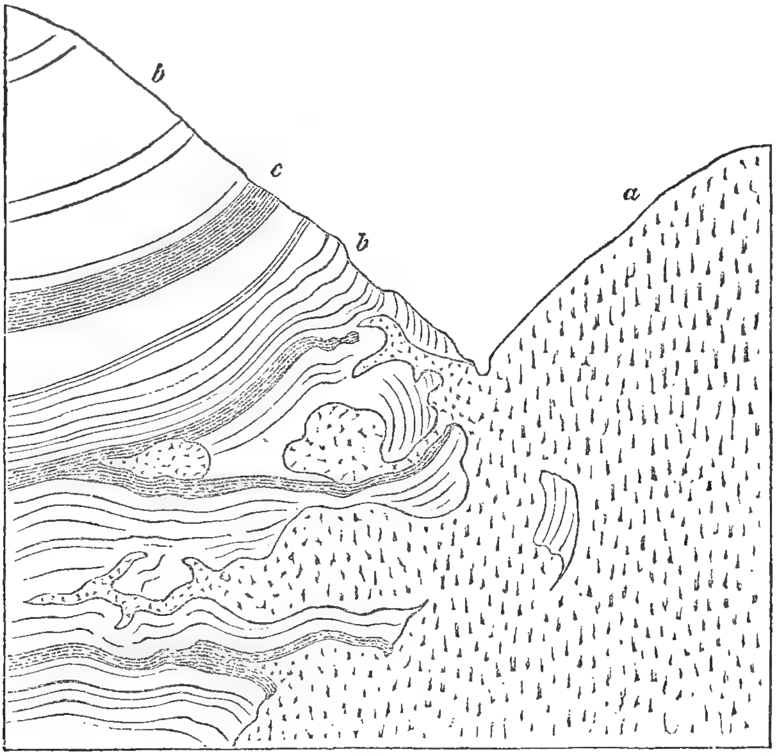


Junction of granite and limestone in Glen Tilt.

a, Granite. *b*, Limestone. *c*, Blue argillaceous schist.

The above diagram from a sketch of Dr. Macculloch, represents the junction of the granite of Glen Tilt in Perthshire, with a mass of stratified limestone and schist. The granite, in this locality, often sends forth so many veins as to reticulate the limestone and schist, the veins diminishing towards their termination to the thickness of a leaf of paper or a thread. In some places fragments of granite appear entangled as it were in the limestone, and are not visibly connected with any larger mass, while sometimes, on the other hand, a lump of the limestone is found in the midst of the granite. The ordinary colour of the limestone of Glen Tilt is lead blue, and its texture large grained and highly crystalline; but where it approximates to the granite, particularly where it is penetrated by the smaller veins, the crystalline texture disappears, and it

assumes an appearance exactly resembling that of horn-stone. The associated argillaceous schist often passes into hornblende slate, where it approaches very near to the granite *.

In the plutonic, as in the volcanic rocks, there is every gradation from a tortuous vein to the most regular form of a dike, such as we have described as intersecting the tuffs and lavas of Vesuvius and Etna. In these dikes of granite, which may be seen, among other places, on the southern flank of Mount Battoch, one of the Grampians, the opposite walls sometimes preserve an exact parallelism for a considerable distance. It is not uncommon for one set of granite veins to intersect another, and sometimes there are three sets, as in the environs of Heidelberg, where the granite of the right bank of the Rhine is seen to consist of three varieties differing in colour, grain, and various peculiarities of mineral composition. One of these, which is evidently the second in age, is seen to cut through an older granite, and another, still newer, traverses both the second and the first. These phenomena were lately pointed out to me by Professor Leonhard at Heidelberg.

In Shetland there are two kinds of granite. One of these, composed of hornblende, mica, felspar, and quartz, is of a dark colour, and is seen underlying gneiss. The other is a red granite which penetrates the former everywhere in veins †.

Granites of different ages.—It was formerly supposed that granite was the oldest of rocks, the mineral product of a particular period or state of the earth formed long antecedently to the introduction of organic beings into the planet. But it is now ascertained that this rock has been produced again and again, at successive eras, with the same characters, penetrating the stratified rocks in different regions, but not always associated with strata of the same age. Nor are organic remains always entirely wanting in the formations invaded by granite, although their absence is more usual. Many well authenticated exceptions to the rule are now established on the authority of

* Macculloch, Geol. Trans., vol. iii. p. 259.

† Macculloch, Syst. of Geol., vol. i. p. 58.

numerous observers, amongst the earliest of whom we may cite Von Buch, who discovered in Norway a mass of granite overlying an ancient secondary limestone, containing orthocerata and other shells and zoophytes*.

A considerable mass of granite in Sky is described by Dr. Macculloch as incumbent on limestone and shale, which are of the age of the English lias†. The limestone, which, at a greater distance from the granite, contains shells, exhibits no traces of them near the junction of the igneous rock, where it has been converted into a pure crystalline marble‡.

This granite of Sky was at first termed 'Syenite,' by which name many geologists have denominated the more modern granites; but authors have entirely failed in their attempt to establish a distinction between granites and syenites on mineralogical characters. The latter have sometimes been defined to consist of a triple compound of felspar, quartz, and hornblende, but the oldest granites are very commonly composed of these ingredients only. In his later publications Dr. Macculloch has with great propriety, we think, called the plutonic rock of Sky a granite§.

In different parts of the Alps a comparatively modern granite is seen penetrating through secondary strata, which contain belemnites, and other fossils, and are supposed to be referrible to the age of the English lias. According to the observations of M. Elie de Beaumont and Hugi, masses of this granite are sometimes found partially overlying the secondary beds, and altering them in a manner which we shall describe more particularly when we treat of the changes in composition and structure superinduced upon sedimentary deposits in contact with Plutonic rocks|| (see wood-cut, No. 90, p. 371).

In such examples we can merely affirm, that the granite is

* Travels through Norway and Lapland, p. 45. London, 1813.

† See Murchison, Geol. Trans., 2nd Series, vol. ii. part ii. p. 311—321.

‡ Western Islands, vol. i. p. 330.

§ Syst. of Geol., vol. i. p. 150.

|| Elie de Beaumont, Sur les Montagnes de l'Oisans, Mem. de la Soc. d'Hist. Nat. de Paris, tome v. Hugi, Natur. Historische Alpenreise, Soleure, 1830.

newer than a secondary formation containing belemnites, but we can form no conjecture when it originated, not even whether it be of secondary or tertiary date. It is, indeed, very necessary to be on our guard against the inference that a granite is usually of about the same age as the group of strata into which it has intruded itself, for in that case we shall be inclined to assume rashly that the granites found penetrating a more modern secondary rock, such as the lias for example, are much newer than those found invading strata older than the carboniferous series. The contrary may often be true, for the plutonic rock which was last in a melted state, may not have been forced up anywhere so near the surface as to enter into the newer groups of strata, and it may have been injected into a part of the earth's crust formed exclusively of the older sedimentary formations.

'In a deep series of strata,' says Dr. Macculloch, 'the superior or distant portions may have been but slightly disturbed, or have entirely escaped disturbance, by a granite which has not emitted its veins far beyond its immediate boundary. However certain, therefore, it may be, that any mass of granite is posterior to the gneiss, the micaceous schist, or the argillaceous schists, which it traverses, or into which it intrudes, we are unable to prove that it is not also posterior to the secondary strata that lie above them *.'

There can be no doubt, however, that some granites are more ancient than any of our regular series which we identify by organic remains, because there are rounded pebbles of granite, as well as gneiss, in the conglomerates of the oldest fossiliferous groups.

Distinction between volcanic and plutonic rocks—Trap.—The next point to consider is the distinction between the plutonic and volcanic rocks. When geologists first began to examine attentively the structure of the northern parts of Europe, they were almost entirely ignorant of the phenomena of existing volcanos, and when they met with basalt and other

* Syst. of Geol., vol. i. p. 136.

rocks composed chiefly of augite, hornblende, and felspar, which are now admitted by all to have been once in a state of fusion, they were divided in opinion whether they were of igneous or of aqueous origin. We have shown in our sketch of the history of geology in the first volume, how much the polemical controversies on this subject retarded the advancement of the science, and how slowly the analogy of the rocks in question to the products of burning volcanos was recognized.

Most of the igneous rocks first investigated in Germany, France, and Scotland, were associated with marine strata, and in some places they occurred in tabular masses or platforms at different heights, so as to form on the sides of some hills a succession of terraces or *steps*, from which circumstance they were called 'trap' by Bergman (from *trappa*, Swedish for a staircase), a name afterwards adopted very generally into the nomenclature of the science.

When these trappean rocks were compared with lavas produced in the atmosphere, they were found to be in general less porous and more compact; but in this instance the terms of comparison were imperfect, for a set of rocks, formed almost entirely under water, was contrasted with another which had cooled in the open air.

Yet the ancient volcanos of Central France were classed, in reference probably to their antiquity, with the trap rocks, although they afford perfect counterparts to existing volcanos, and were evidently formed in the open air. Mont Dor and the Plomb du Cantal, indeed, may differ in many respects from Vesuvius and Etna in the mineral constitution and structure of their lavas; but it is that kind of difference which we must expect to discover when we compare the products of any two active volcanos, such as Teneriffe and Hecla, or Hecla and Cotopaxi.

The amygdaloidal structure in many of the trap formations proves that they were originally cellular and porous like lava, but the cells have been subsequently filled up with silex, carbonate of lime, zeolite, and other ingredients which form the nodules. Dr. Macculloch, after examining with great attention the

igneous rocks of Scotland, observes 'that it is a mere dispute about terms to refuse to the ancient eruptions of trap the name of submarine volcanos, for they are such in every essential point, although they no longer eject fire and smoke*.'

The same author also considers it not improbable that some of the volcanic rocks of the same country may have been poured out in the open air†.

The recent examination of the igneous rocks of Sicily, especially those of the Val di Noto, has proved that all the more ordinary varieties of European trap have been produced under the waters of the sea in the Newer Pliocene period, that is to say, since the Mediterranean has been inhabited by a great proportion of the existing species of testacea. We are, therefore, entitled to feel the utmost confidence, that if we could obtain access to the existing bed of the ocean, and explore the igneous rocks poured out within the last 5000 years beneath the pressure of a sea of considerable depth, we should behold formations of modern date scarcely distinguishable from the most ancient trap rocks of our island. We cannot, however, expect the identity to be perfect, for time is ever working some alteration in the composition of these mineral masses, as, for example, by converting porous lava into amygdaloids.

Passage from trap into granite.—If a division be attempted between the trappean and volcanic rocks, it must be made between different parts of the same volcano,—nay even the same rock, which would be called 'trap,' where it fills a fissure and has assumed a solid crystalline form on slow cooling, must be termed volcanic, or lava, where it issues on the flanks of the mountain. Some geologists may perhaps be of opinion that melted matter, which has been poured out in the open air, may be conveniently called volcanic, while that which appears to have cooled at the bottom of the sea, or under pressure, but at no great depth from the surface, may be termed 'trap;' but we believe that such distinctions will lead only to confusion, and that we must consider trap and volcanic as synonymous. On the other hand, the difficulty of discrimi-

* Syst. of Geol., vol. ii. p. 114. † Ibid.

nating the volcanic from the plutonic rocks is sufficiently great; for we must draw an arbitrary line between them, there being an insensible passage from the most common forms of granite into trap or lava.

'The ordinary granite of Aberdeenshire,' says Dr. Macculloch, 'is the usual ternary compound of quartz, felspar, and mica, but sometimes hornblende is added to these, or the hornblende is substituted for the mica. But in many places a variety occurs which is composed simply of felspar and hornblende, and in examining more minutely this duplicate compound, it is observed in some places to assume a fine grain, and at length to become undistinguishable from the greenstones of the trap family. It also passes in the same uninterrupted manner into a basalt, and at length into a soft claystone, with a schistose tendency on exposure, in no respect differing from those of the trap islands of the western coast*.' The same author mentions, that in Shetland a granite composed of hornblende, mica, felspar, and quartz, graduates in an equally perfect manner into basalt†.

It would be easy to multiply examples to prove that the granitic and trap-rocks pass into each other, and are merely different forms which the same elements have assumed according to the different circumstances under which they have consolidated from a state of fusion. What we have said respecting the mode of explaining the different texture of the central and external parts of the Vesuvian dikes may enable the reader in some measure to comprehend how such differences may originate ‡.

The same lava which is porous where it has flowed over from the crater, and where it has cooled rapidly and under comparatively slight pressure, is compact and porphyritic in the dike. Now these dikes are evidently the channels of communication between the crater and the volcanic foci below; so that we may suppose them to be continuous to the depth of several hundred fathoms, or perhaps two or three miles, or even more; and the fluid matter below, which cools and consoli-

* Syst. of Geol., vol. i. p. 157. † Ibid., p. 158.

‡ See above, p. 124.

dates slowly under so enormous a pressure, may be supposed to acquire a very distinct texture and become granite.

If it be objected that we do not find in mountain-chains volcanic dikes passing upwards into lava, and downwards into granite, we may answer that our vertical sections are usually of small extent, and it is enough that we find in certain localities a transition from trap to porous lava, and in others a passage from granite to trap. It should also be remembered, that a large proportion of the igneous rocks, when first formed, cannot be supposed to reach the surface, and these may assume the usual granitic texture without graduating into trap, or into such lava and scoriæ as are found on the flanks of a volcanic cone.

Theory of the origin of granite at all periods.—It is not uncommon for lava-streams to require more than ten years to cool in the open air, and a much longer period where they are of great depth. The melted matter poured out from Jorullo, in Mexico, in the year 1759, which accumulated in some places to the height of 550 feet, was found to retain a high temperature half a century after the eruption*. For what immense periods, then, must we not conclude that great masses of subterranean lava in the volcanic foci may remain in a red hot or incandescent state, and how gradual must be the process of refrigeration! This process may be sometimes retarded for an indefinite period, by the accession of fresh supplies of heat, for we find that the lava in the crater of Stromboli, one of the Lipari islands, has been in a state of constant ebullition for the last 2000 years, and we must suppose this fluid mass to communicate with some cauldron or reservoir of fused matter below. In the Isle of Bourbon, also, where there has been an emission of lava once in every two years for a long period, we may infer that the lava below is permanently in a state of liquefaction.

When melted matter is injected into the fissures of a contiguous rock at a considerable depth, it may cool rapidly if that rock has not acquired a high temperature; but suppose, on he

* See vol. i. p. 378, and Second Edition, p. 433.

contrary, that it has been heated, and still continues for centuries, or thousands of years, at a red heat, the vein may acquire a highly crystalline texture.

The great pressure of a superincumbent mass, and exclusion from contact with air or water, are probably the usual conditions necessary to produce the granitic texture; but the same may sometimes be superinduced at a slighter distance from the surface by slow refrigeration, when additional supplies of heat check, from time to time, the cooling process and cause it to be indefinitely protracted.

If, for the reasons above alluded to, we conceive it probable that plutonic rocks have originated in the nether parts of the earth's crust, as often as the volcanic have been generated at the surface, we may imagine that no small quantity of the former class has been forming in the recent epoch, since we suppose that about 2000 volcanic eruptions may occur in the course of every century, either above the waters of the sea or beneath them *.

We may also infer, that during each preceding period, whether tertiary or secondary, there have been granites and granitiform rocks generated, because we have already discovered the monuments of ancient volcanic eruptions at almost every period.

In the next chapter we shall endeavour to show, that in consequence of the great depths at which the plutonic rocks usually originate, and the manner in which they are associated with the older sedimentary strata of each district, it is rarely possible to determine with exactness their relative age. Yet there is reason to believe that the greater portion of the plutonic formations now visible are of higher antiquity than the oldest secondary strata. We shall also endeavour to point out, that this opinion is by no means inconsistent with the theory that *equal* quantities of granite may have been produced in succession, during *equal periods* of time, from the earliest to the most modern epochs.

* See vol. i. chap. xxii.

CHAPTER XXVI.

On the stratified rocks usually called 'primary'—Proofs from the disposition of their strata that they were originally deposited from water—Alternation of beds varying in composition and colour—Passage of gneiss into granite—Alteration of sedimentary strata by trappean and granitic dikes—Inference as to the origin of the strata called 'primary'—Conversion of argillaceous into hornblende schist—The term 'Hypogene' proposed as a substitute for primary—'Metamorphic' for 'stratified primary' rocks—No regular order of succession of hypogene formations—Passage from the metamorphic to the sedimentary strata—Cause of the high relative antiquity of the visible hypogene formations—That antiquity consistent with the hypothesis that they have been produced at each successive period in equal quantities—Great volume of hypogene rocks supposed to have been formed since the Eocene period—Concluding remarks.

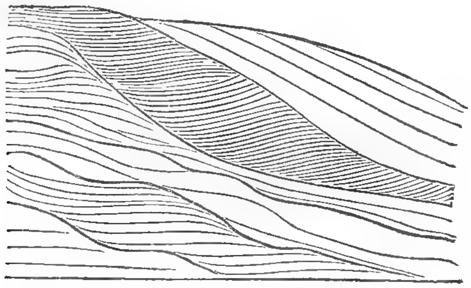
ON THE STRATIFIED ROCKS CALLED 'PRIMARY.'

We stated in the last chapter, that the rocks usually termed 'primary' are divisible into two natural classes, the stratified and the unstratified. The propriety of the term stratified, as applied to the first-mentioned class, will not be questioned when the rocks so designated are carefully compared with strata known to result from aqueous deposition.

Mode of stratification.—If we examine gneiss, which consists of the same materials as granite, or mica-schist which is a binary compound of quartz and mica, or clay-slate, or any other member of the so-called primary division, we find that it is made up of a succession of beds, the planes of which are, to a certain extent, parallel to each other, but which frequently deviate from parallelism in a manner precisely analogous to that exhibited by sedimentary formations of all ages. The resemblance is often carried farther, for in the crystalline series we find beds composed of a great number of layers placed diagonally, as we have shown to be the case in the

Crag and other formations *. This disposition of the layers

No. 89.



Lamination of clay-slate, Montagne de Seguinat, near Gavarnie, in the Pyrenees.

is illustrated in the accompanying diagram, in which I have represented carefully the stratification of a coarse argillaceous schist, which I examined in the Pyrenees, part of which approaches in character to a green and blue roofing slate, while part is extremely quartzose, the whole mass passing downwards into micaceous schist. The vertical section here exhibited is about three feet in height, and the layers are sometimes so thin that fifty may be counted in the thickness of an inch. Some of them consist of pure quartz.

The stratification now alluded to must not be confounded with that fissile texture sometimes observed in the older rocks, by virtue of which they divide in a direction different both from the general planes of stratification and from the planes of those transverse layers of which a single stratum may be made up.

Another striking point of analogy between the stratification of the crystalline formations and that of the secondary and tertiary periods is the alternation in each of beds varying greatly in composition, colour, and thickness. We observe, for instance, gneiss alternating with layers of black hornblende-schist, or with granular quartz or limestone, and the interchange of these different strata may be repeated for an indefinite number of times. In like manner, mica-schist alternates with chlorite-schist, and with granular limestone in thin layers.

As we observe in the secondary and tertiary formations

* See above, p. 173.

strata of pure siliceous sand alternating with micaceous sand and with layers of clay, so in the 'primary' we have beds of pure quartz rock alternating with mica-schist and clay-slate. As in the secondary and tertiary series we meet with limestone alternating again and again with micaceous or argillaceous sand, so we find in the 'primary' gneiss and mica-schist alternating with pure and impure granular limestones.

Passage of gneiss into granite—If, then, reasoning from the principle that like effects have like causes, we attribute the stratification of gneiss, mica-schist, and other associated rocks, to sedimentary deposition from a fluid, we encounter this difficulty, that there is often a transition from gneiss, one of the stratified series, into granite, which, as we have shown, is of igneous origin. Gneiss is composed of the same ingredients as granite, and its texture is equally crystalline. It sometimes occurs in thick beds, and in these the rock is often quite undistinguishable, in hand specimens, from granite; yet the lines of stratification are still evident. These lines imply deposition from water, while the passage into granite would lead us to infer an igneous origin. In what manner can we reconcile these apparently conflicting views? The Huttonian hypothesis offers, we think, the only satisfactory solution of this problem. According to that theory, the materials of gneiss were originally deposited from water in the usual form of aqueous strata, but these strata were subsequently altered by their proximity to granite, and to other plutonic masses in a state of fusion, until they assumed a granitiform texture. The reader will be prepared, by what we have said of granite, to conclude, that when voluminous masses of melted rock have been for ages in an incandescent state, in contact with sedimentary deposits, they must produce some alteration in their texture, and this alteration may admit of every intermediate gradation between that resulting from perfect fusion, and the slightest modification which heat can produce.

The geologist has been conducted, step by step, to this

theory by direct experiments on the fusion of rocks in the laboratory, and by observation of the changes in the composition and texture of stratified masses, as they approach or come in contact with igneous veins and dikes. In studying the latter class of phenomena, we have the advantage of examining the condition of the rock at some distance from the dike where it has escaped the influence of heat, and its state where it has been near to, or in contact with, the fused mass. The changes thus exhibited may be regarded as the results of a series of experiments, made on a great scale by nature under every variety of condition, both as relates to the mineral ingredients of the rocks, the intensity of heat or pressure, the celerity or slowness of the cooling process, and other circumstances.

Strata altered by volcanic dikes—Plas Newydd.—We shall select a few examples of these alterations in illustration of our present argument. One of the most interesting is the modification of strata in the proximity of a volcanic dike near Plas Newydd, in Anglesea, described by Professor Henslow. The dike is 134 feet wide, and consists of basalt (dolerite of some authors), a compound of felspar and augite. Strata of shale and argillaceous limestone, through which it cuts perpendicularly, are altered to a distance of thirty, or even in some places to thirty-five feet, from the edge of the dike. The shale, as it approaches the basalt, becomes gradually more compact, and is most indurated where nearest the junction. Here it loses part of its schistose structure, but the separation into parallel layers is still discernible. In several places the shale is converted into hard porcellanous jasper. In the most hardened part of the mass the fossil shells, principally *Productæ*, are nearly obliterated, yet even here their impressions may frequently be traced. The argillaceous limestone undergoes analogous mutations, losing its earthy texture as it approaches the dike, and becoming granular and crystalline. But the most extraordinary phenomenon is the appearance in the shale of numerous crystals of analcime and garnet, which are

distinctly confined to those portions of the rock affected by the dike*. Garnets have been observed, under very analogous circumstances, in High Teesdale, by Professor Sedgwick, where they also occur in shale and limestone, altered by a basaltic dike. This discovery is most interesting, because garnets often abound in mica-schist, and we see in the instances above cited, that they did not previously exist in the shale and limestone, and that they have evidently been produced by heat in rocks in which the marks of stratification have not been effaced.

Stirling Castle.—To select another example: we find in the rock of Stirling Castle, a calcareous sandstone fractured and forcibly displaced by a mass of green-stone, which has evidently invaded the strata in a melted state. The sandstone has been indurated, and has assumed a texture approaching to hornstone near the junction. So also in Arthur's Seat and Salisbury Craig, near Edinburgh, a sandstone is seen to come in contact with greenstone, and to be converted into a jaspideous rock †.

Antrim.—In the north of Ireland, in several parts of the county of Antrim, chalk, with flints, is traversed by basaltic dikes. The chalk is converted into granular marble near the basalt, the change sometimes extending eight or ten feet from the wall of the dike, being greatest at that point, and thence gradually decreasing till it becomes evanescent. 'The extreme effect,' says Dr. Berger, 'presents a dark brown crystalline limestone, the crystals running in flakes as large as those of coarse *primitive* limestone; the next state is saccharine, then fine-grained and arenaceous; a compact variety having a porcellanous aspect, and a bluish-grey colour succeeds; this, towards the outer edge, becomes yellowish-white, and insensibly graduates into the unaltered chalk. The flints in the altered chalk usually assume a grey yellowish colour ‡.' All

* Trans. of Cambridge Phil. Soc., vol. i. p. 406.

† Illust. of Hutt. Theory, § 253 and 261. Dr. Macculloch, Geol. Trans., 1st series, vol. ii. p. 305.

‡ Dr. Berger, Geol. Trans., 1st series, vol. iii. p. 172.

traces of organic remains are effaced in that part of the limestone which is most crystalline.

As the carbonic acid has not been expelled, in this instance, from that part of the rock which must be supposed to have been melted, the change must have taken place under considerable pressure; for we know, by the experiments of Sir James Hall, that it would require the weight of about 1700 feet of sea-water, which would be equivalent to the pressure of a column of liquid lava 600 feet high, to prevent this acid from being given off.

Another of the dikes of the north-east of Ireland has converted a mass of red sandstone into hornstone *. By another, the slate-clay of the coal-measures has been indurated, and has assumed the character of flinty slate †; and in another place the slate-clay of the lias has been changed into flinty slate, which still retains numerous impressions of ammonites ‡. One of the greenstone dikes of the same country passes through a bed of coal, which it reduces to a cinder for the space of nine feet on each side §.

The secondary sandstones in Sky are converted into solid quartz in several places where they come in contact with veins or masses of trap; and a bed of quartz, says Dr. Macculloch, has been found near a mass of trap, among the coal-strata of Fife, which was in all probability a stratum of ordinary sandstone subsequently indurated by the action of heat ‖.

Alterations of strata in contact with granite.—Having selected these from innumerable examples of mutations caused by volcanic dikes, we may next consider the changes produced by the contiguity of plutonic rocks. To some of these we have already adverted, when speaking of granite veins, and endeavouring to establish the igneous origin of granite. We mentioned that the main body of the Cornish granite sends forth veins through the killas of that country ¶, a coarse argillaceous schist, which is converted into hornblende-schist

* Rev. W. Conybeare, Geol. Trans., 1st series, vol. iii. p. 201.

† Ibid., p. 205.

‡ Ibid. p. 213, and Playfair, Illust. of Hutt. Theory, § 253.

§ Ibid., p. 206.

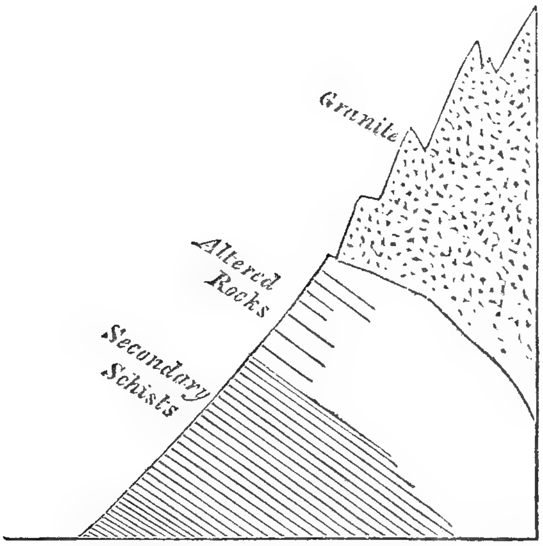
‖ Syst. of Geol., vol. i. p. 206.

¶ See diagram, No. 87.

near the contact with the veins. These appearances are well seen at the junction of the granite and killas in St. Michael's Mount, a small island nearly 300 feet high, situated in the bay, at the distance of about three miles from Penzance.

In the department of the Hautes Alpes, in France, near Vizille, M. Elie de Beaumont traced a black argillaceous limestone, charged with belemnites to within a few yards of a mass of granite. Here the limestone begins to put on a

No. 90.



Junction of granite with Jurassic or oolite strata in the Alps, near Champoleon.

granular texture, but is extremely fine-grained. When nearer the junction it becomes grey and has a saccharoid structure. In another locality, near Champoleon, a granite composed of quartz, black mica, and rose-coloured felspar, is observed partly to overlie the secondary rocks, producing an alteration which extends for about thirty feet downwards, diminishing in the inferior beds which lie farthest from the granite. (See woodcut No. 90.) In the altered mass the argillaceous beds are hardened, the limestone is saccharoid, the grits quartzose, and in the midst of them is a thin layer of an imperfect granite. It is also an important circumstance, that near the point of contact both the granite and the secondary rocks become metalliferous, and contain nests and small veins of blende, galena, iron, and copper pyrites. The stratified rocks become harder and more

crystalline, but the granite, on the contrary, softer and less perfectly crystallized near the junction *.

It will appear from sections described by M. Hugi, that some of the secondary beds of limestone and slate, which are in a similar manner overlaid by granite, have been altered into gneiss and mica-schist †. Some of these altered sedimentary formations are supposed, by M. Elie de Beaumont, to be of the age of the lias of England, and others to be even as modern as the jurassic or oolite formations.

We can scarcely doubt, in these cases, that the heat communicated by the granitic mass reduced the contiguous strata to semi-fusion, and that on cooling slowly the rock assumed a crystalline texture. The experiments of Gregory Watt prove, distinctly, that a rock need not be perfectly melted in order that a re-arrangement of its component particles should take place, and that a more crystalline texture should ensue. We may easily suppose, therefore, that all traces of shells and other organic remains may be destroyed, and that new chemical combinations may arise, without the mass being so fused as that the lines of stratification should be wholly obliterated.

In allusion to the passage from granite to gneiss before described, Dr. Macculloch remarks, that 'in numerous parts of Scotland, where the leading masses of gneiss are schistose, evenly stratified, and scarcely ever traversed by granite veins, they become contorted and irregular as they approach the granite; assuming also the granitic character, and becoming intersected by veins, numerous in proportion to the vicinity of the mass. The conclusion,' he adds, 'is obvious; the fluid granite has invaded the aqueous stratum as far as its influence could reach, and thus far has filled it with veins, disturbed its regularity and generated in it a new mineral character, often absolutely confounded with its own. And if the more remote beds, and those alternating with other rocks, are not thus

* Elie de Beaumont, Sur les Montagnes de l'Oisans, &c., Mem. de la Soc. d'Hist. Nat. de Paris, tome v.

† Natur. Historische Alpenreise, Soleure, 1830.

affected, it is not only that it has acted less on those, but that, if it had equally affected them, they never could have existed, or would have been all granitic and venous gneiss *.

According to these views, gneiss and mica-schist may be nothing more than micaceous and argillaceous sandstones altered by heat, and certainly, in their mode of stratification and lamination, they correspond most exactly. Granular quartz may have been derived from siliceous sandstone, compact quartz from the same. Clay-slate may be altered shale, and shale appears to be clay which has been subjected to great pressure. Granular marble has probably originated in the form of ordinary limestone, having in many instances been replete with shells and corals now obliterated, while calcareous sands and marls have been changed into impure crystalline limestones.

Associated with the rocks termed primary we meet with anthracite, just as we find beds of coal in sedimentary formations, and we know that, in the vicinity of some trap dikes, coal is converted into anthracite. 'Hornblende schist,' says Dr. Macculloch, 'may at first have been mere clay, for clay or shale is found altered by trap into Lydian stone, a substance differing from hornblende-schist almost solely in compactness and uniformity of texture †.' 'In Shetland,' remarks the same author, 'argillaceous schist (or clay-slate), when in contact with granite, is sometimes converted into hornblende-schist, the schist becoming first siliceous, and ultimately, at the contact, hornblende-schist ‡.'

This theory, if confirmed by observation and experiment, may enable us to account for the high position in the series usually held by clay slate relatively to hornblende-schist, as also to gneiss and mica-schist, which so commonly alternate with hornblende-schist. For we must suppose the heat which alters the strata to proceed, in almost all cases, from below upwards, and to act with greatest intensity on the inferior strata. If, therefore, several sets of argillaceous strata or shales be superimposed upon each other in a vertical series of beds in the same

* Syst. of Geol., vol. ii. p. 145. † Ibid., vol. i. p. 210. ‡ Ibid., p. 211

district, the lowest of these will be converted into hornblende-schist, while the uppermost may continue in the condition of clay-slate.

The term 'Hypogene' proposed for Primary.—If our readers have followed us in the train of reasoning explained in this and the preceding chapter, they must already be convinced that the popular nomenclature of Geology, in reference to the so called 'primary' rocks, is not only imperfect, but in a great degree founded on a false theory; inasmuch as some granites and granitic schists are of origin posterior to many secondary rocks. In other words, some *primary* formations can already be shown to be newer than many *secondary* groups—a manifest contradiction in terms.

Yet granite and gneiss, and the families of stratified and unstratified rocks connected with each, belong to one great natural division of mineral masses, having certain characters in common, and it is therefore convenient that the class to which they belong should receive some common name—a name which must not be of chronological import, and must express, on the one hand, some peculiarity equally attributable to granite and gneiss (to the plutonic as well as the *altered* rocks), and which, on the other, must have reference to characters in which those rocks differ both from the volcanic and from the *unaltered* sedimentary strata. We propose the term 'hypogene' for this purpose, derived from ὑπο, *subter*, and γινομαι, *nascor*, a word implying the theory that granite and gneiss are both *nether-formed* rocks, or rocks which have not assumed their present form and structure at the surface. It is true that gneiss and all stratified rocks must have been deposited originally at the surface, or on that part of the surface of the globe which is covered by water; but according to the views explained in this and the foregoing chapter, they could never have acquired their crystalline texture, unless acted upon by heat under pressure in those regions, and under those circumstances where the plutonic rocks are generated.

The term 'Metamorphic' proposed for stratified primary.—

We divide the hypogene rocks, then, into the unstratified, or plutonic, and the *altered* stratified. For these last the term 'metamorphic' (from μετα, *trans*, and μοϱφη, *form*) may be used. The last-mentioned name need not, however, be often resorted to, because we may speak of hypogene *strata*, hypogene *limestone*, hypogene *schist*, and this appellation will suffice to distinguish the formations so designated from the plutonic rocks. By referring to the table (No. I.) at the close of this chapter, the reader will see the chronological relation which we conceive the two classes of hypogene rocks to bear to the strata of different ages.

No order of succession in hypogene formations.—When we regard the tertiary and secondary formations simply as mineral masses uncharacterized by organic remains, we perceive an indefinite series of beds of limestone, clay, marl, siliceous sand, sandstone, coal, and other materials, alternating again and again without any fixed or determinate order of position. The same may be said of the hypogene formations, for in these a similar want of arrangement is manifest, if we compare those occurring in different countries. Gneiss, mica-schist, hornblende-schist, quartz rock, hypogene limestone, and the rest, have no invariable order of superposition, although, for reasons above explained, clay-slate must usually hold a superior position relatively to hornblende schist.

We do not deny, that in a particular mountain-chain, a chronological succession of hypogene formations may be recognized, for the same reason that in a country of limited extent there is an order of position in the secondary and tertiary rocks, limestone predominating in one part of the series, clay in another, siliceous sand in a third, and so of other compounds. It is probable that a similar prevalence of a regular order of arrangement in the hypogene series throughout certain districts, led the earlier geologists into a belief, that they should be able to fix a definite order of succession for the various members of this great class throughout the world.

That expectation has not been realized; yet was it more reasonable than the doctrine of the universality of certain rocks which were admitted to be of sedimentary origin; for there is certainly a remarkable identity in the mineral character of the hypogene formations, both stratified and unstratified, in all countries; although the notion of a uniform order of succession in the different groups must be abandoned.

The student may, perhaps, object to the views above given of the relation of the sedimentary and metamorphic rocks, on the ground that there is frequently, indeed usually, an abrupt passage from one to the other. This phenomenon, however, admits of the same explanation as the fact, that the beds of lakes and seas are now frequently composed of hypogene rocks. In these localities the hypogene formations have been brought up to the surface and laid bare by denudation. New sedimentary strata are thrown down upon them, and in this manner the two classes of rocks, the aqueous and the hypogene, come into immediate contact, without any gradation from one to the other. As we suppose the plutonic and metamorphic rocks to have been uplifted at all periods in the earth's history, so as to have formed the bottom of the ocean and of lakes, by the same operations which have carried up marine strata to the summits of lofty mountains, we must suppose the juxtaposition of the two great orders of rocks now alluded to, to have been a necessary result of all former revolutions of the globe.

But occasionally a transition is observable from strata containing shells, and displaying an evident mechanical structure, to others which are partially altered, and from these again we sometimes pass insensibly into the hypogene series. Some of the argillaceous-schists in Cornwall are of this description, being undistinguishable from the hypogene schists of many countries, and yet exhibiting, in a few spots, faint traces of organic remains. In parts of Germany, also, there are schists which, from their chemical condition, are identical with hypogene-schists, yet are interstratified with greywacke, a rock probably

modified by heat, but which contains casts of shells, and often displays unequivocal marks of being an aggregate of fragments of pre-existing rocks.

Those geologists who shrink from the theory, that all the hypogene strata, so beautifully compact and crystalline as they are, have once been in the state of the ordinary mud, clay, marl, sand, gravel, limestone, and other deposits now forming beneath the waters, resort, in their desire to escape from such conclusions, to the hypothesis, that *chemical causes* once acted with intense energy, and that by their influence more crystalline strata were precipitated; but this theory appears to us to be as mysterious and unphilosophical as the doctrine of a 'plastic virtue,' introduced by the earlier writers to explain the origin of fossil-shells and bones.

Relative age of the visible hypogene rocks.—We shall now return to the subject already in part alluded to at the close of the last chapter—the relative age of the hypogene rocks as compared to the secondary. How far are they entitled in general to the appellation of 'primary,' in the sense of being anterior in age to the period of the carboniferous strata, in which last we include the greywacke and many of the rocks commonly called transition? It is undoubtedly true that we can rarely point out metamorphic or plutonic rocks which can be proved to have been formed in any secondary or tertiary period. We can, in some instances, demonstrate, as we have already shown, that there are granites of posterior origin to certain secondary strata, and that *secondary* strata have sometimes been converted into the *metamorphic*. But examples of such phenomena are rare, and their rarity is quite consistent with the theory, that the hypogene formations, both stratified and unstratified, have been always generated in equal quantities during periods of equal duration.

We conceive that the granite and gneiss, formed at periods more recent than the carboniferous era, are still for the most part concealed, and those portions which are visible can rarely be shown, by geological evidence, to have originated during

secondary periods. It is very possible, for example, that considerable tracts of hypogene strata in the Alps may be altered oolite, altered lias, or altered secondary rocks inferior to the lias; but we can scarcely ever hope to substantiate the fact, because, whenever the change of texture is complete, no characters remain to afford us any insight into the probable age of the mass. Where granite happens to have intruded itself in such a manner as partially to overlie a mass of lias or other strata, as in the case before alluded to (diagram No. 90, p. 371), we may prove that *fossilliferous* strata have become gneiss, mica-schist, clay-slate, or granular marble; but if the action of the heat upon the strata had been more intense, the same inferences could not have been drawn. It might then have been supposed that no Alpine hypogene strata were newer than the carboniferous period.

The metamorphic strata of Scotland are certainly in great part older than the carboniferous, which are found incumbent upon them in an unaltered state; but it appears that secondary deposits as new, or newer than the lias, have come in contact, in the Western Islands, with granite, and have there assumed the hypogene texture.

A considerable source of difficulty and misapprehension, in regard to the antiquity of the metamorphic rocks, may arise from the circumstance of their having been deposited at one period, and having assumed their crystalline texture at another. Thus, for example, if an Eocene granite should invade the lias and superinduce a hypogene structure, to what period shall we refer the altered strata? Shall we say that they are metamorphic rocks of the Eocene or Liassic eras? They assumed their stratified form when the animals and plants of the lias flourished; they became metamorphic during the Eocene period. It would be preferable in such instances, we think, to consider them as hypogene strata of the Eocene period, or of that in which they were altered; yet it would rarely be possible to establish their true age. We should know the granite, to which the change of texture was due, to be newer than the lias

which it penetrated; but there would rarely be any date to show that it might not have been injected at the close of the Liassic period, or at some much later era.

The metamorphic rocks must be the oldest, that is to say, they must lie at the bottom of each series of superimposed strata, because the influence of the volcanic heat proceeds from below upwards; but the hypogene strata of one country may be, and frequently are, of a very different age from those of another. The greater part, however, of the visible hypogene rocks are, we believe, more ancient than the carboniferous formations. In the latter, we frequently discover pebbles of hypogene rocks, namely, granite, gneiss, mica-schist, and clay-slate; and the carboniferous rocks often rest unchanged upon the hypogene. According to our views of the operations of earthquakes, we ought not to expect plutonic and metamorphic rocks of the more modern eras to have reached the surface generally, for we must imagine many geological periods to elapse before a mass which has put on its particular form far below the level of the sea, can have been upraised and laid open to view above that level. Beds containing marine shells sometimes appear at the height of two or three miles in the principal mountain-chains, but they always belong to formations of considerable antiquity; still more should we be prepared to find the hypogene rocks now in sight to be of high relative antiquity, since, in order to be brought up to view, they must probably have risen from a position far inferior to the bottom of the ocean.

We shall endeavour to elucidate the cause of the great age of the plutonic and metamorphic rocks, *now in sight*, by a familiar illustration. Suppose two months to be the usual time required for passing from some tropical country to our island, and that an annual importation takes place of a certain tropical species of insect, the ordinary term of whose life is two months, and which can only be reared in the climate of that equatorial country. It is evident that no living individuals could ever be seen in England except in extreme old age. The young may come annually into the world in great numbers,

but in order to see them, we must travel to lands near the equator.

In like manner, if the hypogene rocks can only originate at great depths in the regions of subterranean heat, and if it requires many geological epochs to raise them to the surface, they must be very ancient before they make their appearance in the superficial parts of the earth's crust. They may still be forming in every century, and they may have been produced in equal quantities during each successive geological period of equal duration; but in order to see them in a nascent state, slowly consolidating from a state of fusion, or semi-fusion, we must descend into the 'fuelled entrails' of the earth, into the regions described by the poets, where for ages the land has

——— ever burn'd
With solid, as the lake with liquid fire.

As the progress of decay and reproduction by aqueous agency is incessant on the surface of the continents, and in the bed of the ocean, while the hypogene rocks are generated below, or are rising gradually from the volcanic foci, thus there must ever be a remodelling of the earth's surface in the time intermediate between the origin of each set of plutonic and metamorphic rocks, and the protrusion of the same into the atmosphere or the ocean. Suppose the principal source of the Etnean lavas to lie at the depth of ten miles, we may easily conceive that before they can be uplifted to the day several distinct series of earthquakes must occur, and between each of these there might usually be one or more periods of tranquillity. The time required for so great a development of subterranean elevatory movements might well be protracted until the deposition of a series of sedimentary rocks, equal in extent to all our secondary and tertiary formations, had taken place. We conceive, therefore, that the relative age of the *visible* plutonic and metamorphic rocks, as compared to the unaltered sedimentary strata, must always be determined by the relations of two forces,—the power which uplifts the hypogene rocks, and that aqueous agency which degrades and renovates the earth's

surface; or, in other words, it must depend on the quantity of aqueous action which takes place between two periods, that when the heated and melted rocks are cooled and consolidated in the nether regions, and that when the same emerge to the day.

Volume of hypogene rocks supposed to have been formed since the Eocene period.—If we were to indulge in speculations on the probable quantity of hypogene formations, both stratified and unstratified, which may have been formed beneath Europe and the European seas since the commencement of the Eocene period, we should conjecture, that the mass has equalled, if not exceeded in volume, the entire European continents. The grounds of this opinion will be understood by reference to what we have said of the causes which may have upheaved part of Sicily to a great height above the level of the sea since the beginning of the Newer Pliocene period*. If the theory which, in that instance, attributes the disturbance and upheaving of the superficial strata to the action of subterranean heat be deemed admissible, the same argument will apply with no less force to every other district, elevated or depressed, since the commencement of the tertiary period.

But we have shown, in our remarks on the map of Europe, in the second volume, that the conversion of sea into land, since the Eocene period, embraces an area equal to the greater part of Europe, and even those tracts which had in part emerged before the Eocene era, such as the Alps, Apennines, and other mountain-chains, have risen to the additional altitude of from 1000 to 4000 feet since that era. We have also stated the probability of a great amount of subsidence and the conversion of considerable portions of European land into sea during the same period—changes which may also be supposed to arise from the influence of subterranean heat.

From these premises we conclude, that the liquefaction and alteration of rocks by the operation of volcanic heat at suc-

* See above, p. 107.

cessive periods, has extended over a subterranean space equal at least in area to the present European continent, and often through a portion of the earth's crust 4000 feet or more in thickness.

The principal effect of these volcanic operations in the nether regions, during the tertiary periods, or since the existing species began to flourish, has been to heave up to the surface hypogene formations of an age anterior to the carboniferous. We imagine that the repetition of another series of movements, of equal violence, might upraise the plutonic and metamorphic rocks of many of the secondary periods; and if the same force should still continue to act, the next convulsions might bring up the *tertiary* and *recent* hypogene rocks, by which time we imagine that nearly all the sedimentary strata now in sight would either have been destroyed by the action of water, or would have assumed the metamorphic structure, or would have been melted down into plutonic and volcanic rocks.

At the close of this chapter the reader will find a table of the chronological relations of the principal divisions of rocks according to the views above set forth. The sketch is confessedly imperfect, but it will elucidate our theory of the connexion which may exist between the hypogene rocks of different periods, and the alluvial, volcanic, and sedimentary formations. A second table is added, containing the names of some of the principal groups of sedimentary strata mentioned in this work, arranged in their order of superposition.

Concluding Remarks.—In our history of the progress of geology, in the first volume, we stated that the opinion originally promulgated by Hutton, 'that the strata called *primitive* were mere altered sedimentary rocks,' was vehemently opposed for a time, the main objection to the theory being its supposed tendency to promote a belief in the past eternity of our planet. Previously the absence of animal and vegetable remains in the so-called primitive strata, had been appealed to, as proving that there had been a period when the planet was uninhabited by living beings, and when, as was

also inferred, it was uninhabitable, and, therefore, probably in a nascent state.

The opposite doctrine, that the oldest visible strata might be the monuments of an antecedent period, when the animate world was already in existence, was declared to be equivalent to the assumption, that there never was a beginning to the present order of things. The unfairness of this charge was clearly pointed out by Playfair, who observed, 'that it was one thing to declare that we had not yet discovered the traces of a beginning, and another to deny that the earth ever had a beginning.'

We regret, however, to find that the bearing of our arguments in the first volume has been misunderstood in a similar manner, for we have been charged with endeavouring to establish the proposition, that 'the existing causes of change have operated with absolute uniformity from all eternity *.'

It is the more necessary to notice this misrepresentation of our views, as it has proceeded from a friendly critic whose theoretical opinions coincide in general with our own, but who has, in this instance, strangely misconceived the scope of our argument. With equal justice might an astronomer be accused of asserting, that the works of creation extend throughout *infinite* space, because he refuses to take for granted that the remotest stars now seen in the heavens are on the utmost verge of the material universe. Every improvement of the telescope has brought thousands of new worlds into view, and it would, therefore, be rash and unphilosophical to imagine that we already survey the whole extent of the vast scheme, or that it will ever be brought within the sphere of human observation.

But no argument can be drawn from such premises in favour of the infinity of the space that has been filled with worlds; and if the material universe has any limits, it then follows that it must occupy a minute and infinitessimal point in infinite space. So, if in tracing back the earth's history, we arrive at the monuments of events which may have happened millions of ages

* Quarterly Review, No. 86, Oct. 1830, p. 464.

before our times, and if we still find no decided evidence of a commencement, yet the arguments from analogy in support of the probability of a beginning remain unshaken; and if the past duration of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere moment of the past, a mere infinitessimal portion of eternity.

It has been argued, that as the different states of the earth's surface, and the different species by which it has been inhabited, have had each their origin, and many of them their termination, so the entire series may have commenced at a certain period. It has also been urged, that as we admit the creation of man to have occurred at a comparatively modern epoch—as we concede the astonishing fact of the first introduction of a moral and intellectual being, so also we may conceive the first creation of the planet itself.

We are far from denying the weight of this reasoning from analogy; but although it may strengthen our conviction, that the present system of change has not gone on from eternity, it cannot warrant us in presuming that we shall be permitted to behold the signs of the earth's origin, or the evidences of the first introduction into it of organic beings.

In vain do we aspire to assign limits to the works of creation in *space*, whether we examine the starry heavens, or that world of minute animalcules which is revealed to us by the microscope. We are prepared, therefore, to find that in *time* also, the confines of the universe lie beyond the reach of mortal ken. But in whatever direction we pursue our researches, whether in time or space, we discover everywhere the clear proofs of a Creative Intelligence, and of His foresight, wisdom, and power.

As geologists, we learn that it is not only the present condition of the globe that has been suited to the accommodation of myriads of living creatures, but that many former states also have been equally adapted to the organization and habits of prior races of beings. The disposition of the seas, continents, and islands, and the climates have varied; so it appears that the species have been changed, and yet they have all

been so modelled, on types analogous to those of existing plants and animals, as to indicate throughout a perfect harmony of design and unity of purpose. To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical inquiries, or even of our speculations, appears to us inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an Infinite and Eternal Being.

TABLE I.

Showing the Relations of the Alluvial, Aqueous, Volcanic, and Hypogene Formations of different ages.

Periods.		Formations.		Some of the Localities where the Formations occur.
I. Recent.	A.	Alluvial.		Beds of existing rivers, &c., vol. ii. ch. xiv.
		Aqueous.	*a.* Marine.	Coral reefs of the Pacific, vol. ii. ch. xviii.
			b. Freshwater.	Bed of Lake Superior, &c., vol. i. ch. xiii.
		Volcanic.		Etna, Vesuvius, vol. i. ch. xix. xx. xxi.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of active volcanos, vol. iii. ch. xxv.
			b. Metamorphic.	*Concealed;* around the foci of active volcanos, vol. iii. ch. xxvi.
II. Tertiary.	1. Newer Pliocene. B.	Alluvial.		Loess of the Rhine—gravel covering the Newer Pliocene strata of Sicily.
		Aqueous.	*a.* Marine.	Val di Noto, Sicily.
			b. Freshwater.	Colle, in Tuscany.
		Volcanic.		Val di Noto, Sicily.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Newer Pliocene volcanos—underneath the Val di Noto, vol. iii. p. 107, and ch. xxv.
			b. Metamorphic.	*Concealed;* near the foci of Newer Pliocene volcanos—underneath the Val di Noto, vol. iii. p. 109, and ch. xxvi.
	2. Older Pliocene. C.	Alluvial.		Norfolk? vol. iii. p. 173.
		Aqueous.	*a.* Marine.	Subapennine formations.
			b. Freshwater.	Near Sienna, vol. iii. p. 160.
		Volcanic.		Tuscany, vol. iii. p. 159.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Older Pliocene volcanos—beneath Tuscany.
			b. Metamorphic.	*Concealed;* probably near the same foci.
	3. Miocene. D.	Alluvial.		Mont Perrier, Auvergne—Orleanais, vol. iii. p. 217.
		Aqueous.	*a.* Marine.	Bordeaux. Dax.
			b. Freshwater.	Saucats, near Bordeaux, vol. iii. p. 207.
		Volcanic.		Hungary, vol. iii. ch. xvi.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Miocene volcanos—beneath Hungary.
			b. Metamorphic.	*Concealed;* probably around the same foci.
	4. Eocene. E.	Alluvial.		Summit of North and South Downs? vol. iii. p. 311.
		Aqueous.	*a.* Marine.	Paris and London basins.
			b. Freshwater.	Isle of Wight—Auvergne.
		Volcanic.		Oldest volcanic rocks of the Limagne d'Auvergne, vol. iii. ch. xix.
		Hypogene.	*a.* Plutonic.	*Concealed;* foci of Eocene volcanos—beneath the Limagne d'Auvergne.
			b. Metamorphic.	*Concealed;* probably near the same foci.

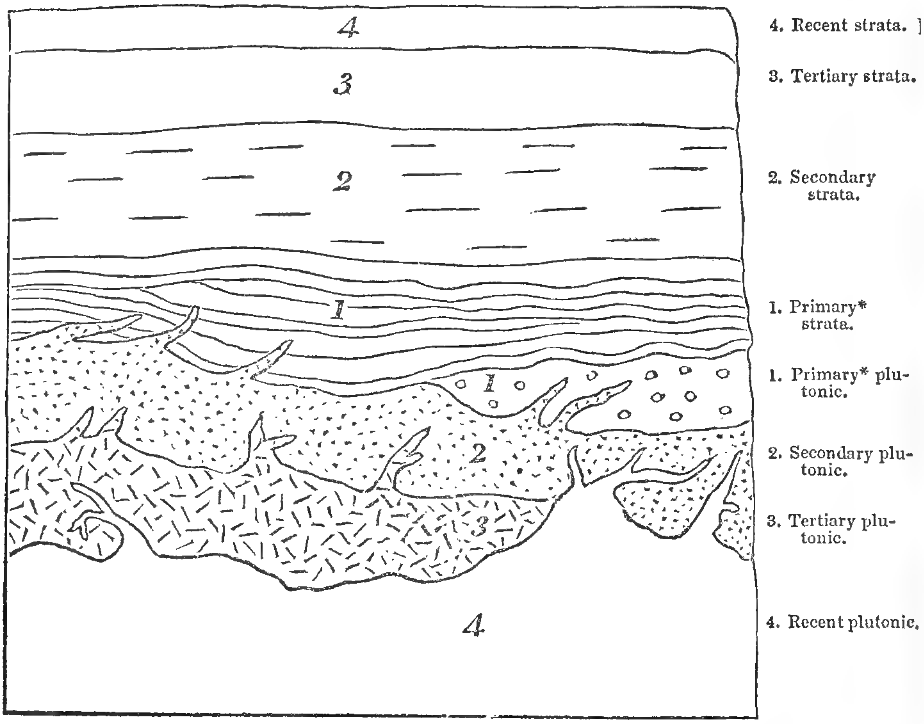
TABLE I. *continued.*

Periods.		Formations.		Some of the Localities where the Formations occur.
III. Secondary.	1. Cretaceous group. F. Table II.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Wiltshire. North Downs. Flamborough Head.
		Volcanic.	. . . . . .	Northern flanks of the Pyrenees? near Dax?
		Hypogene.	a. Plutonic. b. Metamorphic.	
	2. Wealden group. G. Table II.	Alluvial.	. . . . . .	Portland 'Dirt-bed.'
		Aqueous.	a. Marine. b. Freshwater.	Weald of Surrey, Kent, and Sussex, vol. iii. ch. xxi.
		Volcanic.		
		Hypogene.	a. Plutonic. b. Metamorphic.	
	3. Oolite group. H. Table II.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Oxford. Bath. Jura chain.
		Volcanic.	. . . . . .	Hebrides?
		Hypogene.	a. Plutonic. b. Metamorphic.	*Concealed;* beneath the Hebrides.
	4. Lias group. I. Table II.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Lyme Regis. Whitby. Aberthaw.
		Volcanic.	. . . . . .	Hebrides?
		Hypogene.	a. Plutonic. b. Metamorphic.	Alps? ch. xxvi. p. 371. Valorsine in Savoy?
	5. New Red Sandstone group. K. Table II.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Cheshire. Staffordshire. Vosges. Westphalia (Muschelkalk).
		Volcanic.	. . . . . .	Near Exeter, Devon.
		Hypogene.	a. Plutonic. b. Metamorphic.	*Concealed;* beneath Devonshire?
	6. Carboniferous group. L. Table II.	Alluvial.		
		Aqueous.	a. Marine. b. Freshwater.	Clifton. Dudley. Mendip. [Fife. Coal measures of Somersetshire and
		Volcanic.	. . . . . .	Forfarshire. Edinburgh. Durham. High Teesdale.
		Hypogene.	a. Plutonic.	*Concealed;* beneath Edinburgh, Northumberland, Durham.
			b. Metamorphic.	Near the Plutonic rocks of the same period.

DIAGRAM

Shewing the relative position which the Plutonic and Sedimentary Formations of different ages may occupy; (in illustration of TABLE I.)

No. 91.



In the above diagram an attempt is made to shew the inverted order in which the sedimentary and plutonic formations may occur in the earth's crust; subterposition in the plutonic, like superposition in the sedimentary rocks, being for the most part characteristic of a newer age. By aid of this illustration, and what we have said in Chap. 25 and 26, the reader will comprehend why so large a portion of the plutonic rocks of later periods are concealed, and why the more ancient of this class have risen nearest to the surface, so as to have been denuded in some regions and exposed to view.

* The primary formations here mentioned are those, whether stratified or unstratified, which are older than the carboniferous deposits.

TABLE II.

Showing the Order of Superposition, or Chronological Succession, of the principal Sedimentary Deposits or Groups of Strata in Europe.

This Table is referred to in the Glossary, and includes the Secondary Formations alluded to in this Work, but not described in detail.

Periods and Groups.		Names of the principal Members and general Mineral nature of the Formation.		Some of the Localities where the Formation occurs.
I. Recent Period.		The deposits of this period are for the most part concealed under existing lakes and seas.		
I. Recent Period.	A	Consolidated sandy and gravelly beds (*a*), travertin limestones (*b*), calcareous sandstones with broken shells (*c*), coral limestone, consisting of corals, shells, &c. (*d*)		*a.* Delta of the Rhone. *b.* Tivoli, and other parts of Italy. *c.* Shore of island of Guadaloupe. *d.* Coral reefs in Pacific, &c.
II. Tertiary Period.		Marine.	Freshwater.	
II. Tertiary Period.	B Newer Pliocene.	*Limestone*, sands, clays, sandstones, conglomerates, marls with gypsum; containing *marine* fossils (*a*).	Sands, clays, sandstones, lignites, &c.; containing *land* and *freshwater* fossils (*b*).	*a.* Sicily, Ischia, Morea? *b.* Colle in Tuscany.
II. Tertiary Period.	C Older Pliocene.	*Subapennine marl, Subapennine yellow sand, English 'crag,'* and other deposits, as in B, containing *marine* fossils (*a*).	Similar deposits to B; containing *land* and *freshwater* fossils (*b*).	*a.* Subapennine formations, Perpignan, Nice, Norfolk and Suffolk. *b.* Near Sienna, &c.
II. Tertiary Period.	D Miocene.	*Faluns of the Loire*, and other deposits of similar mineral composition with B and C, containing *marine* fossils (*a*).	Similar deposits to B and C; containing *land* and *freshwater* fossils (*b*).	*a.* Touraine, Bordeaux, Valley of Bormida, Superga near Turin, Basin of Vienna. *b.* Saucats, twelve miles south of Bordeaux.

TABLE II. *continued.*

Periods and Groups.		Names of the principal Members and general Mineral nature of the Formation.		Some of the Localities where the Formation occurs.
II. Tertiary Period, *continued.*	E Eocene.	*Calcaire Grossier* (*a*), *plastic clay*, sands, sandstones, &c., with *marine* fossils (*b*).	*Calcaire siliceux*—sandstones and conglomerates, red marl, green and white marls, limestone, gypseous marls, —with land and freshwater fossils (*c*).	*a*. Paris basin. *b*. Paris, London, and Hampshire basins, Isle of Wight. *c*. Paris Basin, Isle of Wight, Auvergne, Velay, Cantal.
III. Secondary Period.	F Cretaceous Group.	1. *Maestricht Beds.*—Earthy white limestone with siliceous masses, resembling chalk (marine).		St. Peter's Mount, Maestricht.
		2. *Chalk with flints* (marine).		North and South Downs, and parts of the intervening Weald of Kent, Surrey, and Sussex. Isle of Wight, coasts of Hampshire and Dorsetshire, Yorkshire, North of Ireland.
		3. Chalk without flints (marine).		
		4. *Upper green sand* (marine).—Marly stone, and sand with green particles; layers of calcareous sandstone.		
		5. *Gault* (marine).—Blue clay, with numerous fossils, passing into calcareous marl in the lower parts.		
		6. *Lower green sand* (marine).—Grey, yellowish, and greenish sands, ferruginous sands and sandstones, clays, cherts, and siliceous limestones.		
	G Wealden Group.	1. *Weald clay* (freshwater).—Clay, for the most part without intermixture of calcareous matter, sometimes including thin beds of sand and shelly limestone.		1, 2. Extensively developed in the central parts of Kent, Surrey, and Sussex. 3. Isle of Purbeck, in Dorsetshire.
		2. *Hastings sands* (freshwater).—Grey, yellow, and reddish-brown sands, sandstones, clays, calcareous grits passing into limestone.		
		3. *Purbeck beds* (freshwater).—Various kinds of limestones and marls.		

TABLE II. *continued.*

Periods and Groups.		Names of the principal Members and general Mineral nature of the Formation.	Some of the Localities where the Formation occurs.
III. Secondary Period, *continued.*	H. Oolite, or Jura Limestone Group.	1. *Portland beds* (marine).—Coarse shelly limestone, fine-grained white limestone, compact limestone — all more or less of an oolitic structure; beds of cherts.	Isle of Portland, Tisbury in Wiltshire, Aylesbury.
		2. *Kimmeridge clay* (marine).—Blue and greyish-yellow slaty clay, containing gypsum, bituminous slate (Kimmeridge coal).	Near Kimmeridge on coast of Dorsetshire—Sunning Well, near Oxford.
		3. *Coral rag* (marine).—Calcareous shelly freestones, largely oolitic; coarse limestone, full of corals; yellow sands; calcareous siliceous grits.	Headington, near Oxford—Farringdon, in Berkshire—Calne and Steeple Ashton in Wiltshire—Somersetshire.
		4. *Oxford clay* (marine).—Dark blue tenacious clay with septaria, bituminous shale, sandy limestone (Kelloway rock), iron pyrites, gypsum.	New Malton, in Yorkshire—Lincolnshire — Cambridgeshire — Huntingdonshire, and midland counties—abundantly near Oxford—Somersetshire—Dorsetshire.
		5. *Cornbrash* (marine).—Grey or bluish rubbly limestone, separated by layers of clay.	Malmsbury, Atford, Wraxall, Chippenham.
		6. *Forest marble* (marine).—Calcareo-siliceous sand and gritstone; thin fissile beds of limestone, with clay partings; coarse shelly limestone.	Whichwood Forest, Oxfordshire—Frome, south-east of Bath.
		7. *Great oolite* (marine).—White and yellow oolitic calcareous freestone, coarse shelly limestone, layers of clay. Oolitic limestone, with remains of land animals, birds, amphibia, plants, sea-shells (*a*).	Kettering, in Northamptonshire—Bath—Burford, in Oxfordshire—Bradford, in Wiltshire. (*a*) Stonesfield, near Woodstock, Oxfordshire.
		8. *Inferior oolite* (marine).—Fuller's earth, soft freestone, sand with calcareous concretions.	Cotteswold Hills — Dundry Hill, near Bristol.
		Limestones of various qualities, clays, sands, and sandstone, containing the same fossils as those occurring in the series of the oolitic group of England, constitute the main body of the Jura chain of mountains, and cover vast tracts of country in Germany.	

TABLE II. *continued.*

Periods and Groups.		Names of the principal Members and general Mineral nature of the Formation.	Some of the Localities where the Formation occurs.
III. Secondary Period, *continued.*	I Lias Group.	*Lias* (marine).—Blue, white, and yellow earthy limestone, usually in thin beds, interstratified with clay, often slaty and bituminous. Dark blue marl, with a few irregular rubbly limestone beds—sandy marlstone.	Lyme Regis, in Dorsetshire, and in many parts of Somersetshire, Gloucestershire, Warwickshire, Nottinghamshire, and Yorkshire—in Sutherlandshire, the Hebrides, and North of Ireland. In France, and, to a considerable extent, in Germany.
	K New Red Sandstone Group.	1. *Keuper,* or *variegated marls.*—Red, grey, green, blue, and white marls, sandstones, conglomerates, and shells, containing gypsum and rock-salt.	Neighbourhood of Vosges mountains, and many parts of Wurtemberg and Westphalia, and other parts of Germany.
		2. *Muschelkalk* (marine).—Grey, blue, and blackish limestone, with many fossils, particularly encrinites; siliceous layers and nodules; magnesian limestone, marls of different colours, gypsum, and rock-salt.	Extensively developed in Germany and France. Hitherto no beds in England have been identified with the formation.
		3. *Variegated sandstone.* — Red, white, blue, and green siliceo-argillaceous sandstone, often micaceous, and containing gypsum and rock-salt.	Nottinghamshire — Yorkshire. It is uncertain whether the variegated sandstone of England belongs to the Keuper formation of Germany, or to the variegated sandstone which lies under the Muschelkalk in Westphalia, Wurtemberg, the Vosges, &c.
		4. *Magnesian limestone* (marine).—Compact shelly limestone, yellow magnesian limestone, marl slate, red marl, and gypsum.	Nottinghamshire, Derbyshire, Yorkshire, Durham, Northumberland. Departments of Saone and Loire, Hartz mountains, Thuringia, Westphalia.
		5. *Red conglomerate.*—Sandstones, conglomerates, sands, and marls.	Neighbourhood of Exeter—Yorkshire — Durham—Westphalia—Wurtemberg—Vosges mountains.

TABLE II. *continued.*

Periods and Groups.		Names of the principal Members and general Mineral nature of the Formation.	Some of the Localities where the Formation occurs.
III. SECONDARY PERIOD, *continued.*	L Carboniferous Group.	1. *Coal measures* (freshwater ?).—Sandstones, grits, conglomerates, clays with ironstone, shales, and limestone, interstratified with beds of coal.	Northumberland, Durham, Yorkshire, Lancashire, Derbyshire, Staffordshire, Gloucestershire, Somersetshire, South Wales, Valleys of the Forth and Clyde. District of Liege, Westphalia, Silesia, Bohemia, &c.
		2. *Mountain limestone* (marine).—Grey, compact, and crystalline limestone, abounding in lead ore in North of England, and alternating with coal measures in Scotland.	Mendip Hills, Somersetshire, Derbyshire, Yorkshire, Lancashire, Westmoreland, Durham, Northumberland, Lanarkshire, Linlithgowshire, many parts of Ireland. North-west of Germany, Belgium, North of France.
		3. *Old red sandstone.*—Coarse and fine siliceous sandstones and conglomerates of various colours, red predominating.	Extensively developed in Shropshire and Herefordshire, Brecknockshire, Dumfriesshire, Forfarshire. Silesia, Bohemia.
		4. *Grauwacke* and *transition limestone* (marine).—Coarse and fine slates, sandstones, and conglomerates—crystalline limestones.	Westmoreland, Cumberland, Wales, Somersetshire, Devonshire, South of Scotland, South of Ireland. North of France, North-west of Germany, &c.

INSTRUCTIONS

FOR USING

M. DESHAYES'S TABLES OF SHELLS,

APPENDIX I.

THE object of these Tables is to give a list, *not* of the *characteristic* shells of the different tertiary formations, of which some figures are given in plates 1, 2, and 3, but to show the connexion of different periods by indicating the shells *common* to two or more periods, or common to some tertiary period and to the *recent* epoch.

The names also of a considerable number of species are given, as being found common to two or more formations of the *same* tertiary period. The localities where the fossil species are met with, and the known habitations of the living species, are also given.

No allusion is made to any *secondary* fossil shells; the word *fossil*, therefore, must always be understood to refer to tertiary formations.

The number of species of recent and fossil shells which were examined and compared in constructing these tables amounted to 7,816, as follows:—

	Living Species.	Fossil Species.
Univalves	3,616	2,098
Bivalves	1,164	938
	4,780	3,036

Of these 3,036 fossil species, 426 were identified with individuals found among the 4,780 living species; 123 of them are only known in a fossil state, but are mentioned as being common to more than one tertiary *period;* and 233 are enumerated by name, although not common to two tertiary periods, or to some tertiary period and the recent epoch, merely because they have been found in two or more formations of the *same*

period. Thus the number of fossil species named in the tables amounts to 782, consisting of—

Species found both living and fossil	426
Species fossil only, but common to more than one tertiary period	123
Species fossil only, and named merely as found in two or more formations of the same period	233
	782

A few will be found without specific names, because they have not yet been described or named by any authors.

The tables are continuous from p. 2 to p. 45, and the description of each species extends across two pages.

The following examples will best illustrate the object of the tables. If we take the first genus, Aspergillum (p. 2), we find that—

Column 1 gives the name of the genus.

,, 2 shows that four living species of the genus are known to M. Deshayes.

,, 3 that he has seen one fossil species.

,, 4 is left blank, because the single fossil species has not yet been identified with any living species.

,, 5 is also blank, because the fossil species is only known in one period or formation.

,, 6 is also blank, because the fossil species not having been identified with a living species, it was unnecessary to mention the habitation of any of the four living species.

The columns of the three periods are left blank, because the fossil species has not been found in more than one period. In the column of localities on the right of the right-hand page, in the subdivision headed Bordeaux, the figure 1 denotes that one species of fossil Aspergillum has been found in that locality.

To select another example: if we take the genus Solen (p. 2), we find that—

Column 2 shows that twenty-six living species of the genus are known to M. Deshayes.

,, 3 that he has seen nineteen fossil species of the genus.

Column 4 gives the name of the species Solen *vagina*, because that species is found both living and fossil.

„ 5 is left blank, because the names of those species only are placed in this column which have no living analogues, but are found in more than one period, or in more than one *formation* of the *same period*. [Thus, in the next line, Solen siliquarius has no living analogue, but it occurs in two formations of the Miocene period, viz. at Bordeaux and in Touraine.]

„ 6 shows that the *living* species of Solen vagina inhabits the European Ocean and Mediterranean.

The two asterisks in the column of the Pliocene period show that the species is found in two formations of that period, viz. in the Subapennine hills and the English crag.

The asterisk in the column of the Miocene period shows that this species is found in the basin of Vienna.

The word Baden in the next column indicates that the species is also found fossil in that locality.

The column of the Eocene period is blank, because the shell has not been found in any formation belonging to that period.

The figures in the column of localities will be understood by what we said above. In summing up these figures it will be found that they amount to thirty-one, whereas it is stated, in the third column of the left-hand page, that only nineteen fossil species have been found. The disagreement arises from this—that the same species occur in more than one locality, and thus come to be counted more than once in the column of localities.

N.B. In some cases, before the totals of the species in the columns of localities can tally with the figures in the third column, the species enumerated in the supplementary table of localities, p. 46, must be taken into account.

A note of interrogation added to the asterisk (*?) indicates a doubt as to the correct identification of the shell, either because the shell is a variety which has a somewhat distant analogy to the recognized type of

the species, or because the specimen examined was in rather an imperfect state.

The specific names of the tertiary fossil shells which have been found by M. Deshayes to belong to one period only, and for which he has not yet discovered any living analogues, are *not* given, as their enumeration would have required more space than could be allotted to such a subject in a treatise on Geology; but their aggregate number is included in the subdivisions of the column in the right-hand page headed 'No. of species in each genus in the following localities,' and in the supplementary table, p. 46.

APPENDIX I.

TABLES OF FOSSIL SHELLS,

BY

MONS$^{R.}$ G. P. DESHAYES,

Member of the Geological Society of Paris, &c.

N.B. For a full explanation of the object of these Tables, and instructions as to the manner of using them, see the preceding four pages.

*

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIO: Sicily.	Italy, Subap.	English Crag.	Various Localitie
Aspergillum	4	1	. . . . . .	. . . . . .	. . . .	. .	. .	. .	. . .
Clavagella . .	2	7	aperta . . .	. . . .	Mediterr. Indian Ocean	*	. .	. .	. . .
——— . .	. .	. .	. . . . . .	coronata . .	. . . .	. .	. .	. .	. . .
——— . .	. .	. .	. . . . . .	bacillaris . .	. . . .	*	. .	. .	. . .
Septaria . .	1								
Teredina . .	. .	2	. . . . . .	personata . .	. . . .	. .	. .	. .	. . .
Teredo . . .	5	5	. . . . . .	new species .	. . . .	. .	. .	. .	. . .
Pholas . . .	15	9	candida . .	. . . . .	Temp. Europe	. .	. .	*?	. . .
Fistulana . .	5	7	gigantea . .	. . . . .	Indian Ocean .	. .	. .	. .	. . .
——— . .	. .	. .	hians . . .	. . . . .	Mediterr. . . .	. .	*	. .	. . .
——— . .	. .	. .	. . . . . .	ampullaria .	. . . .	. .	. .	. .	. . .
Solen . . .	26	19	Vagina . . .	. . . .	European Ocean Mediterr.	. .	*	*	. . .
———. . . .	. .	. .	. . . . . .	siliquarius .	. . . .	. .	. .	. .	. . .
———. . . .	. .	. .	Legumen .	. . . . .	Mediterr. . . .	. .	*	. .	. . .
———. . . .	. .	. .	coarctatus .	. . . . .	ibid.	*	*	. .	. . .
———. . . .	. .	. .	strigilatus .	. . . . .	ibid.	. .	*	. .	. . .
———. . . .	. .	. .	candidus . .	. . . . .	ibid.	*	*	. .	. . .
———. . . .	. .	. .	Siliqua . . .	. . . . .	ibid.	*	. .	. .	. . .
Pholadomya	1	1	. . . . . .	. . . . . .	. . . .	. .	. .	. .	. . .
Glycimeris .	1								
Panopœa . .	2	3	Aldrovandi .	. . . . .	Mediterr. . . .	*	*	. .	Morea .
Mya	4	5	truncata . .	. . . .	Temp. Europ. and	. .	. .	. .	Uddevalla
——. . . .	. .	. .	arenaria . .	. . . .	Northern Ocean	. .	. .	*	. . .
——. . . .	. .	. .	Tugon . . .	. . . . .	Senegal . . .	. .	. .	. .	Morea .
Thracia . .	2	4	corbuloides .	. . . . .	Mediterr. . . .	*	. .	. .	. . .
———. . . .	. .	. .	pubescens .	. . . . .	ibid.	*	. .	. .	. . .
Hemicyclostera	1	2	new species .	. . . .	Europ. Ocean & Mediterr.	*	. .	. .	. . .
Lutraria . .	11	6	elliptica . .	. . . . .	ibid. ibid. .	*	*	. .	. . .
———. . . .	. .	. .	rugosa . . .	. . . . .	Indian Ocean .	. .	*	. .	. . .
———. . . .	. .	. .	new species .	. . . . .	Senegal . . .	. .	. .	. .	. . .
Mactra . . .	32	14	albina . . .	. . . . .	ibid.	. .	. .	. .	. . .
———. . . .	. .	. .	solida . . .	. . . . .	European Ocean	. .	. .	*	. . .
———. . . .	. .	. .	crassatella ?	. . . . .	ibid.	. .	. .	*	. . .
———. . . .	. .	. .	triangula . .	. . . . .	Mediterr. . . .	. .	*	. .	Morea Perpigna
Mesodesma .	7								
Erycina . .	3	23	. . . . . .	. . . . . .	. . . .	. .	. .	. .	. . .
Crassatella .	9	24	. . . . . .	lamellosa . .	. . . .	. .	. .	. .	. . .
——— .			. . . . . .	tumida . . .	. . . .	. .	. .	. .	. . .
Ungulina . .	1								
Solemya . .	2								
Amphidesma	3	1	. . . . . .	. . . . . .	. . . .	. .	. .	. .	. . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	1										
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .	2	1	..	..	1	..	..	..	..	..	..	4	1		
..	..	..	..	. . . . . .	..	..	Pauliac .															
..	..	..	..	. . . . . .	*	*	. . . . . .	..	..	1	..	..	..	..	..	..	..	..	1	1		
..	..	..	..	. . . . . .	*	..	Belgium. .	..	..	1	..	..	..	..	..	..	..	..	1	..	..	4
..	..	..	..	. . . . . .	..	..	. . . . . .	..	1	1	..	..	2	2	..	..	..	1	3			
*	..	..	..	. . . . . .	*	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .	..	1	..	..	..	2	..	..	..	..	1	6	1		
..	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	*	Baden . . .	..	..	. . . . . .															
*	*	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	4	5	1	..	4	2	2	..	..	2	..	9	..	2	
..	*	..	*	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	..	1		
..	..	..	..	. . . . . .	..	..	. . . . . .	1	1	..	..	1	..	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	2	..	2	1									
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	2	..	..	..	2										
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	1	..	..	..	..	1									
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	1	2	..	..	2	1	1								
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	1	2	..	3	3	..	..	..	1	1	2	..	1	1
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	1	..	..	..	2	3	..	..	..	..	..	14			
..	..	..	..	. . . . . .	*	*	Valognes . .	..	..	..	..	..	1	1	..	1	2	2	14	4	5	
..	..	..	..	Ronca . . .	*																	
..	..	..	..	. . . . . .	..	..	. . . . . .	1														

GENERA.	No. of Species Living.	Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Corbula . .	10	35	nucleus . .	. . . .	Mediterr. European Seas	*	*	..	. . . . . .
—— . .	..	..	. . . . .	complanata	. . . . . .	..	..	*	. . . . .
—— . .	..	..	. . . . .	striata . . .	. . . . . .	..	..	..	. . . . .
—— . .	..	..	. . . . .	new species .	. . . . . .	..	..	..	. . . . .
Pandora . .	7	3	new species .	. . . . .	Mediterr. . . .	*	..	..	. . . . .
—— . .	..	..	rostrata . .	. . . .	Mediterr. European Ocean	..	*	..	. . . . .
Saxicava . .	5	11	minuta . . .	. . . . .	ibid.	*	..	..	. . . . .
—— . .	..	..	pholadis . .	. . . . .	ibid.	*	..	..	. . . . .
Petricola . .	13	10	ochroleuca .	. . . . .	Mediterr. . . .	..	..	..	. . . . .
—— . .	..	..	lamellosa . .	. . . . .	ibid.	*	..	..	. . . . .
—— . .	..	..	striata . . .	. . . . .	European Ocean	..	..	..	. . . . .
Venerupis .	8	6	Irus	. . . . .	ibid. Mediterr.	*	..	..	. . . . .
Sanguinolaria	2	2	. . . . .	. . . . .	. . . . . .	..	..	..	. . . . .
Psammobia .	18	4	vespertina .	. . . .	Mediterr. European Ocean	*	..	..	. . . . .
—— .	..	..	muricata . .	. . . . .	ibid	..	*	..	. . . . .
Psammotæa	8	1	. . . . .	. . . . .	. . . . . .	..	..	..	. . . . .
Tellina. . .	68	54	strigosa . .	. . . . .	Senegal . . .	..	..	..	. . . . .
—— . . .	..	..	planata . .	. . . . .	Mediterr. . . .	..	*	..	. . . . .
—— . . .	..	..	lacunosa . .	. . . . .	African Ocean	..	*	..	. . . . .
—— . . .	..	..	Oudardii . .	. . . . .	Mediterr. . . .	*	..	..	. . . . .
—— . . .	..	..	tenuis . . .	. . . .	Mediterr. European Ocean	*	..	..	. . . . .
—— . . .	..	..	pulchella . .	. . . . .	ibid.	*	..	..	. . . . .
—— . . .	..	..	Lantivii . .	. . . . .	ibid.	*	..	..	. . . . .
—— . . .	..	..	serrata . . .	. . . . .	ibid.	*	*	..	. . . . .
—— . . .	..	..	exilis . . .	. . . . .	Unknown . .	..	*	..	. . . . .
—— . . .	..	..	new species .	. . . . .	Senegal . . .	..	..	..	. . . . .
—— . . .	..	..	carnaria . .	. . . .	European Ocean Mediterr.	..	..	..	. . . . .
—— . . .	..	..	. . . . .	subrotunda .	. . . . . .	..	..	..	. . . . .
—— . . .	..	..	. . . . .	new species .	. . . . . .	..	..	..	. . . . .
—— . . .	..	..	. . . . .	elliptica . .	. . . . . .	..	*	..	. . . . .
—— . . .	..	..	. . . . .	bipartita . .	. . . . . .	..	..	..	. . . . .
—— . . .	..	..	donacina .	. . . . .	Mediterr. . . .	*			
Tellinides. .	1								
Corbis . . .	2	2	. . . . .	pectunculus	. . . . . .	..	..	..	. . . . .
Lucina. . .	20	59	tigrina . . .	. . . .	Indian Ocean, Senegal	..	..	..	. . . . .
—— . . .	..	..	punctata . .	. . . . .	ibid.	..	..	..	. . . . .
—— . . .	..	..	columbella .	. . . . .	Senegal . . .	..	..	..	. . . . .
—— . . .	..	..	divaricata .	. . . . .	Almost all Seas	*	*		Morea, Baden, Perpignan
—— . . .	..	..	lactea . . .	. . . . .	Mediterr. . . .	*	*	..	. . . . .
—— . . .	..	..	gibbosula. .	. . . . .	Unknown . .	*	*	..	. . . . .
—— . . .	..	..	squamosa. .	. . . . .	Mediterr. . . .	*	..	..	. . . . .
—— . . .	..	..	radula . . .	. . . . .	ibid.	*	..	..	. . . . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	*	. . . . . .	*	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .	1	1	2	2	4	4	4	..	..	2	..	21	5	3	
*	*	..	*	Transylvania	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	1	1	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	5	..	..	..	1	..	1	..	..	..	..	5			
*	*	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	4	..	..	2	2	1	..	..	..	..	2			
*?	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	1	3	..	..	1	..	..	..	..	..	..	2			
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	1	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	. . . . . .	..	..	. . . . . .	1	1	..	..	1	1	1	..	..	..	..	2			
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	1			
*	..	..	..	Volhynia . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	6	9	4	..	8	6	2	..	..	..	..	18	4	6	
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .															
*	*	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	Volhynia .	..	..	. . . . . .															
..	..	..	..	Ronca. . .	*	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	2			
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	*	{ Angers Volhynia	..	..	. . . . . .															
*	*	..	*	Angers . .	*	*	Valognes .	8	6	..	1	12	9	5	..	..	1	1	31	1	7	
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	*	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	PLIOCENE PERIOD. Italy, Subap.	PLIOCENE PERIOD. English Crag.	PLIOCENE PERIOD. Various Localities.
Lucina, *cont.*			amphidesmoides		Mediterr.	*	*		
——				scopulorum					
——				hiatelloides			*		
——				lupinus		*	*		Ischia
Donax	29	15	elongata		Senegal				
——				transversa					
——				new species					
Capsa	2								
Astarte	3	19	incrassata		Mediterr.		*		
——			new species		ibid.	*	*		
——				new species		*	*		
——			Danmoniensis		Temp. Europe			*?	
——				scalaris					
Cyclas	13	2							
Cyrena	14	25		Gravesii					
——				cuneiformis					
——				antiqua					
——				Brongniarti					
——				semistriata					
Galathea	1								
Cyprina	2	7	Islandica		North Seas			*	
——				scutellaria					
——				Pedemontana			*		
——				gigas			*		Perpignan
Cytheræa	85	59	Erycina		Indian Ocean		*		
——			Chione		Senegal, Medit.	*	*		Morea, Perpignan
——			nitidula		Unknown				
——			citrina		New Holland				
——			exoleta		Mediterr. European Ocean	*	*	*	
——			concentrica		Indian Ocean		*		
——			lincta		Medit. Senegal	*	*		
——			rufescens		Mediterr.		*		
——			multilamella		Indian Ocean	*	*		
——				elegans					
——				deltoidea					
——				suberycinoides					
——			Venetiana		Mediterr.	*			
Venus	101	43	verrucosa		Mediterr. European Ocean	*	*	*?	Ischia
——			plicata		Indian Ocean		*		Morea, Perpignan
——			gallina		South Europ. Oc.		*		
——			decussata		Europ. Oc. Aust. Seas, Lam.				

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	Volhynia . .	..	..	. . . . . .	8	6	..	1	12	9	5	..	..	1	1	31	1	7	
*	*	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*?	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	*	. . . . . .	..	..	. . . . . .	..	..	..	..	4	3	3	..	..	2	2	7			
..	*	..	..	Angers. . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	2	2	5	..	1	1	2	..	..	..	3	..	2?	..	4
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	*	..	..	Angers. . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .	..	1	..	..	2	2	..	1	1	1	..	13	4	..	2
*	..	*	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..		Mayence, Belgium															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	..	Belgium	1	3	1	..	1	1	..	1	..	..	..	1	..	..	1
*	..	*	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	*	..	Volhynia . .	..	..	. . . . . .															
*	*?	..	*?	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	..	. . . . . .															
..	..	..	..	. . . . . .	*?	*?	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	. . . . . .	..	..	. . . . . .	5	8	2	..	11	18	7	2	1	3	1	22	5	11	
..	..	*?	..	. . . . . .	..	..	. . . . . .															
..	..	..	*	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	Valognes .															
..	..	..	..	. . . . . .	*	*	. . . . . .															
*	..	..	..	. . . . . .	*	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	*	Salles . . .	..	..	. . . . . .	6	8	3	1	11	5	8	..	..	3	3	9	4	2	
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	..	. . . . . .															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Venus, *cont.*	..	..	radiata . . .	. . . . . .	Mediterr. . . .	*	*	..	. . . . . .
———. . .	..	..	Brongniarti .	. . . . . .	ibid.	*	..	..	. . . . . .
———. . .	..	..	dysera . . .	. . . . .	Indian Ocean Mediterr.	*	*	..	. . . . . .
———. . .	..	..	. . . . . .	Casinoides .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	vetula . . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	new species .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	rotundata . .	. . . .	..	*	..	. . . . . .
———. . .	..	..	geographica	. . . . . .	Mediterr. . . .	*	..	..	. . . . . .
———. . .	..	..	Paphia . . .	. . . . . .	Indian Ocean .	..	..	..	. . . . . .
Venericardia et Cardita	25	50	sulcata . .	. . . . . .	Mediterr. . . .	*	*		Salles, Perpignan
———. . .	..	..	Ajar	. . . . . .	Senegal . . .	..	..	..	. . . . . .
———. . .	..	..	trapezia . .	. . . . .	Mediterr African Ocean	*	..	..	. . . . . .
———. . .	..	..	squamosa . .	. . . . . .	Mediterr. . . .	*	..	..	. . . . . .
———. . .	..	..	crassa . . .	. . . . .	Indian, Afric. & Australian Ocean	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	Jouanetti . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	hippopea . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	planicosta .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	Coravium .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	acuticosta .	. . . .	..	..	..	. . . . . .
———. . .	..	..	intermedia .	. . . . . .	New Holland .	..	*	..	. . . . . .
———. . .	..	..	. . . . . .	angusticosta	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	imbricata . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	new species .	. . . .	..	*	..	. . . . . .
Cardium . .	53	39	ringens . .	. . . . . .	Senegal . . .	..	..	..	. . . . . .
———. . .	..	..	ciliare . . .	. . . . . .	European Ocean	*	*	..	. . . . . .
———. . .	..	..	echinatum .	. . . . . .	ibid. Senegal	*	*	..	. . . . . .
———. . .	..	..	sulcatum . .	. . . . . .	European Ocean	*	*		Salles, Morea, Perpignan
———. . .	..	..	edule . . .	. . . . . .	ibid. Medit. .	*	*	*	Morea . .
———. . .	..	..	tuberculatum	. . . . . .	ibid.	..	*	..	. . . . . .
———. . .	..	..	. . . . . .	multicostatum	. . . .	..	*	..	. . . . . .
———. . .	..	..	planatum . .	. . . . . .	Mediterr. . . .	..	*	..	. . . . . .
———. . .	..	..	. . . . . .	discrepans .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	hians . . .	. . . .	..	*		Perpignan, Morea . .
———. . .	..	..	. . . . . .	semigranulatum	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	porulosum .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	obliquum . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	Lima . . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . . .	verrucosum .	. . . .	..	..	..	. . . . . .
Cypricardia .	4	7	coralliophaga	. . . . . .	Mediterr. . . .	*	*	..	. . . . . .
———. . .	..	..	new species .	. . . . . .	ibid.	*	*	..	. . . . . .
———. . .	..	..	. . . . . .	affinis . . .	. . . .	..	..	..	. . . . . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	..	..	..	..															
..	..	..	..	..	..	..	..															
*	*	..	..	Angers Volhynia	..	..	..															
*	*	..	*	..	..	..	..															
*	*	..	..	..	..	..	..	6	8	3	1	11	5	8	..	..	2	3	9	4	2	
*	*	..	..	..	..	..	..															
*	*	..	..	..	..	..	..															
..	..	..	..	..	..	..	..															
..	..	..	*	..	..	..	..															
..	..	..	..	..	..	..	..															
*	*	..	*	Moravia ..	..	..	..															
*	*	..	*	..	..	..	..															
..	..	..	..	..	..	..	..															
*	*	..	..	..	*	..	..															
*	*	..	*	Moravia ..	..	..	..															
*	*	..	..	..	..	..	..	3	7	5	..	6	6	5	3	1	4	5	16	5	8	2
..	..	..	..	..	*	*	Valognes, Belgium															
..	..	..	..	..	*	*	Valognes															
..	..	..	..	..	*	*	ibid ..															
..	..	..	..	..	..	..	..															
..	..	..	..	..	*	*	Valognes, Belgium															
..	..	..	..	..	*	..	Castelgomberto															
..	..	..	*	..	..	..	..															
*?	..	..	*?	..	..	..	..															
..	..	..	..	..	..	..	..															
*	*?	..	*	Volhynia ..	..	..	..															
..	..	..	..	..	..	..	..															
..	..	..	..	..	..	..	..															
..	..	..	..	..	..	..	..															
*	*	..	..	..	..	..	..															
..	..	..	..	..	..	..	..	4	11	3	..	6	7	3	..	..	5	..	17	6	7	1
*	*	..	..	..	..	..	..															
..	..	..	..	..	..	..	..															
..	..	..	..	..	*	*	..															
..	..	..	..	..	*	*	Valognes															
..	..	..	..	..	*	*	..															
..	..	..	..	..	*	*?	..															
..	..	..	..	..	*	..	Castelgomberto															
..	..	..	..	..	..	..	..															
..	..	..	..	..	..	..	..	2	2	..	..	1	2	1	..	1	..	..	2			
*	*	..	..	..	..	..	..															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Hiatella . .	1								
Isocardia . .	2	3	cor	. . . . . .	European Ocean	*	*	*?	Maryland ?
———. .	..	..	. . . . . .	new species .	. . . . . .	..	..	..	. . . .
Cucullæa . .	1	2	. . . . . .	. . . . . .	. . . . . .	..	..	..	. . . .
Arca. . . .	43	54	semitorta .	. . . . . .	NewHolland, L.	..	..	..	Salles ? .
—.	..	..	Noæ. . . .	. . . . .	Mediterr. Indian Ocean	*	*	..	. . . . .
—.	..	..	tetragona. .	. . . . . .	ibid. ibid.	*	*	..	. . . . .
—.	..	..	umbonata. .	. . . . . .	Jamaica, Senegal	..	..	..	. . . . .
—.	..	..	barbata . .	. . . . .	European Ocean, Senegal	*	*	..	Perpignan
—.	..	..	Magellanica	. . . . . .	Magellan. . .	..	..	..	. . . . .
—.	..	..	Helbingii. .	. . . . . .	Afr. Oc. Senegal	..	..	..	. . . . .
—.	..	..	antiquata . .	. . . . .	Ind. & Afr. Oc. Mediterr.	*	*	..	Perpignan Morea
—.	..	..	rhombea . .	. . . . . .	Indian Ocean .	..	..	..	. . . . .
—.	..	..	clathrata . .	. . . . . .	Unknown. . .	..	..	..	. . . . .
—.	..	..	new species .	. . . . . .	Mediterr. . .	*	..	..	. . . . .
—.	..	..	Gaymardi .	. . . . . .	ibid.	*	..	..	. . . . .
—.	..	..	Quoyi . . .	. . . . . .	ibid.	*	..	..	. . . . .
—.	..	..	. . . . . .	new species .	. . . . . .	..	..	..	. . . . .
—.	..	..	. . . . . .	biangula . .	. . . . . .	..	..	..	. . . . .
—.	..	..	. . . . . .	punctifera. .	. . . . . .	..	..	..	. . . . .
—.	..	..	. . . . . .	quadrilatera.	. . . . . .	..	..	..	. . . . .
—.	..	..	. . . . . .	barbatula . .	. . . . . .	..	..	..	. . . . .
Pectunculus.	19	27	. . . . . .	new species .	. . . . . .	..	..	..	. . . . .
————.	..	..	glycimeris .	. . . . . .	Mediter. Europ. Ocean	*	*	*	Perpignan, Morea
————.	..	..	pilosus . . .	. . . . .	ibid. ibid. . Northern Europe	*	*	*	. . . . .
————.	..	..	violacescens.	. . . . . .	Mediterr. . . .	*	*	..	. . . . .
————.	..	..	. . . . . .	pulvinatus .	. . . . . .	..	..	..	. . . . .
————.	..	..	. . . . . .	terebratularis	. . . . . .	..	..	..	. . . . .
————.	..	..	. . . . . .	angusticostatus	. . . . . .	..	..	..	. . . . .
————.	..	..	. . . . . .	cor	. . . . . .	..	..	..	. . . . .
————.	..	..	. . . . . .	new species .	. . . . . .	..	..	..	. . . . .
————.	..	..	nummarius .	. . . . . .	Mediterr. . .	..	*	..	. . . . .
————.	..	..	. . . . . .	dispar . . .	. . . . . .	..	..	..	. . . . .
Nucula. . .	7	23	margaritacea	. . . . . .	European Ocean	*	*	..	. . . . .
———. . .	..	..	Pella. . . .	. . . . . .	Mediterr. . . .	*	*	..	. . . . .
———. . .	..	..	emarginata .	. . . . . .	ibid.	*	*	..	. . . . .
———. . .	..	..	new species .	. . . . . .	ibid.	*	..	..	. . . . .
———. . .	..	..	. . . . . .	ovata . . .	. . . . . .	..	..	..	. . . . .
Trigonia . .	1								
Castalia . .	1								
Unio. . . .	65	2	. . . . . .	. . . . . .	. . . . . .	..	..	..	. . . . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	*	......	..	*	......	1	1	1?	..	1	1	1	..	..	1	..	1	1		
*	*	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	2			
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	*	......	..	..	......															
*	*	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
..	..	..	..	......	*??	..	......															
*	*	..	..	Angers . .	*	..	Valognes .															
*	*	..	*	Angers, Nantes	..	..	......															
*	*	..	..	......	..	..	......															
*	*	..	..	Angers. . .	..	..	......	9	6	..	..	9	9	8	..	..	3	7	23	7	6	
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	*	..	*	Podolia . .	..	..	......															
..	..	..	..	......	*	*	ibid. . .															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	ibid. . .															
..	..	..	..	......	*	*	ibid. . .															
*	..	..	*	Angers. . .	..	..	......															
*	*	*	*	Volhynia . .	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes .															
..	..	..	..	......	*	..	Belgium .	3	8	2	..	4	3	2	1	1	4	3	9	5	3	2
..	..	..	..	......	*	*	......															
*	*	..	*	Angers. . .	..	..	......															
*	..	..	*	ibid. . . .	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes .															
*	..	..	*	Volhynia . .	*	*	Valognes .															
..	..	..	*	......	..	..	......															
*	*	..	..	......	..	..	......	4	4	2	..	3	3	1	..	..	..	..	6	5	3	2
..	..	..	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes .															
..	..	..	..	......	..	..	......	..	1	..	..	..	..	..	..	..	..	..	..	1		

GENERA.	No. of Species: Living.	Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Anodonta	19	1	. . . . . .	. . . . . .	. . . .	..	..	..	. . . . .
Hyria	3	..							
Iridina	3	..							
Chama	15	20	gryphoides	. . . . . .	Mediterr.	*	*	..	. . . . .
———	..	..	crenulata ?	. . . . . .	Senegal	..	..	..	. . . . .
———	..	..	sinistrorsa	. . . . . .	Mediterr.	*	*	..	Morea
———	..	..	new species	. . . . . .	ibid	*	*	..	. . . . .
———	..	..	. . . . . .	echinulata	. . . .	..	*	..	. . . . .
———	..	..	. . . . . .	rustica	. . . .	..	..	..	. . . . .
———	..	..	. . . . . .	lamellosa	. . . .	..	..	..	. . . . .
Etheria	4								
Tridacna	7	2							
Hippopus	1								
Modiola	29	21	barbata	. . . . . .	Mediterr.	..	*	..	. . . . .
———	..	..	discrepans	. . . . . .	ib. New Holland	..	..	..	. . . . .
———	..	..	lithophaga	. . . . . .	Mediterr. Indian & African Ocean	..	*	..	. . . . .
———	..	..	. . . . . .	argentina	. . . .	..	..	..	. . . . .
Mytilus	42	15	Chemnitzii	. . . . . .	Riv. of Germany	..	..	..	Baden, Central Austria
———	..	..	edulis	. . . . . .	European Ocean	..	..	*	. . . . .
———	..	..	. . . . . .	new species	. . . .	..	*	..	. . . . .
———	..	..	. . . . . .	Brardii	. . . .	..	..	..	. . . . .
Pinna	16	3	nobilis	. . . . . .	Mediterr.	*?	*?	..	Morea
———	..	..	. . . . . .	margaritacea	. . . .	..	..	..	. . . . .
Crenatula	7	..	. . . . . .						
Perna	10	4	. . . . . .	. . . . . .	. . . .	..	..	..	. . . . .
Malleus	6								
Avicula et Meleagrina	30	5	. . . . . .	. . . . . .	. . . .	..	..	..	. . . . .
Lima	8	13	inflata	. . . . . .	Mediterr.	*	*	..	. . . . .
———	..	..	squamosa	. . . . . .	ibid. Afr. Ocean	*	*?	..	. . . . .
———	..	..	linguatula	. . . . . .	Australian Seas Mediterr.	*	..	..	. . . . .
———	..	..	nivea	. . . . . .	Mediterr.	*	*	..	. . . . .
———	..	..	. . . . . .	plicata	. . . .	..	..	..	. . . . .
Pecten	67	60	Jacobæus	. . . . . .	European Ocean	*	*	..	Perpignan
———	..	..	Laurentii	. . . . . .	American Seas Mediterr.	..	*?	..	Corsica ?
———	..	..	pleuronectes	. . . . . .	Indian Ocean	*	*	..	. . . . .
———	..	..	opercularis	. . . . . .	European Ocean	*	*	*	Salles, Perpignan, Morea
———	..	..	inflexus	. . . . . .	Mediterr.	*	..	..	. . . . .
———	..	..	varius	. . . . . .	European Ocean	*	*	..	Morea
———	..	..	ornatus	. . . . . .	Mediterr.	*	..	..	. . . . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	......	..	..	......		1													
..	..	..	..	......	..	..	......															
*?	..	..	*	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	4	4	..	..	1	3	3	..	..	2	2	9	1	2	
*	*	..	*	Angers. . .	..	..	......															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	..	Castelgomberto															
..	..	..	..	......	..	..	......															
..	..	..	..	......	*?	..	......	1	3	..	1	1	2	..	..	..	..	1	16			
*	..	..	..	......	*	..	......															
*	..	..	..	......	*	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	..	..	..	......	..	..	......	..	2	1	2	2	2	1	3	..	3	..	2	..	1	
*	*	*	*	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	*	..	Belgium .	1	1	..	..	1	..	..	..	..	..	..	1	..	..	1
..	..	..	..	......	..	..	......	..	1	..	..	..	..	..	..	..	..	..	1	..	1	
..	..	..	..	......	..	..	......	..	..	..	..	1	..	..	..	..	..	..	4			
*	..	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	4	5	..	..	1	2	1	..	..	..	2	6	..	1	
..	..	..	..	......	..	..	......															
*	*	..	..	Angers . .	*	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	*	......	..	..	......															
..	..	..	..	......	..	..	......	12	14	3	2	7	6	4	..	..	6	3	10	..	4	3
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Pecten, *cont.*	..	..	coarctatus	......	Mediterr.	*	*	..	......
———	..	..	Bruei	......	ibid.	*	..	..	......
———	..	..	Dumasii	......	ibid.	*	..	..	......
———	..	..	distans	......	ibid.	*	*	..	......
———	..	..	pusio	......	ibid.	*	..	..	......
———	..	..	......	flabelliformis	......	..	*	..	......
———	..	..	......	scabrellus	......	..	*		Perpignan, Morea
———	..	..	......	Burdigalensis	......	..	..	..	......
———	..	..	nodosus	......	Indian Ocean	*?	..	..	......
———	..	..	......	benedictus	......	..	..	..	Perpignan
———	..	..	......	striatus	......	..	..	*	......
———	..	..	......	inæquicostalis	......	..	*		Perpignan, Salles
———	..	..	......	plebeius	......	..	..	..	......
———	..	..	......	laticostatus	......	..	*	..	Perpignan
Plicatula	5	7	......	new species	......	..	..	..	......
Spondylus	25	9	gæderopus	......	Mediterr.	*	*	..	......
———	..	..	......	new species	......	..	..	..	......
———	..	..	......	radula	......	..	..	..	......
Gryphæa	1	3	......	......	......	..	..	..	......
Ostrea	54	72	cornucopiæ	......	Indian Ocean	*	..	..	......
———	..	..	edulis	......	European Ocean	*	*	*?	......
———	..	..	Virginica	......	American Ocean	*	..	..	......
———	..	..	hippopus	......	European Ocean	*	..	..	Corsica
———	..	..	......	flabellula	......	..	..	..	......
———	..	..	......	gigantea	......	..	..	..	......
———	..	..	......	edulina	......	..	..	..	......
———	..	..	......	Bellovacina	......	..	..	..	......
———	..	..	......	dorsata	......	..	..	..	......
———	..	..	navicularis	......	Mediterr.	..	*	..	......
———	..	..	Forskali	......	African Ocean, Red Sea	..	*	..	......
———	..	..	......	Virginiana	......	..	..	..	......
———	..	..	......	undata	......	..	..	..	......
———	..	..	......	new species	......	..	..	..	......
———	..	..	new species	......	Mediterr. Indian Ocean	*	*		Perpignan, Salles, Morea
Hinnites	2	4	......	Cortesi	......	..	*	..	......
Vulsella	5	1	......	......	......	..	..	..	......
Placuna	3	1	papyracea	......	Red Sea	..	..	..	Egypt
Anomia	10	8	ephippium	......	Mediterr. European Ocean	*	*	*	Perpignan
———	..	..	electrica	......	ibid.	*	*	..	......
———	..	..	......	costata	......	..	*?	..	......
———	..	..	......	dubia	......	..	..	..	......

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	..	..	..	......	..	..	......															
*	*	..	*	Angers. . .	..	..	......	12	14	3	2	7	6	4	..	..	6	3	10	..	4	3
*	..	..	*	Transylvania	..	..	......															
..	..	..	..	......	..	..	......															
..	*	..	..	Angers, Doué	..	..	......															
..	*	..	..	ibid. . . .	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	*		Belgium, Valognes															
..	..	..	..	......	..	..	......															
*	*	..	..	Angers. . .	..	..	......	..	..	..	..	1	2	1	..	..	..	2	3	..	2	
..	..	..	..	......	..	..	......															
*	*	..	..	Angers . .	..	..	Castelgomberto ?	1	2	..	..	1	1	1	1	..	1	2	4	..	1	
..	..	..	..	......	*		Valognes															
..	..	..	..	......	..	..	......	..	1	..	..	..	..	..	..	..	..	..	2			
..	..	..	..	......	..	..	......															
..	..	..	*?	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes Belgium															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	Belgium .	5	13	1	..	7	4	6	..	..	4	2	42	10	9	3
..	..	..	..	......	*	*	......															
..	..	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
*	*	..	..	Montpellier .	..	..	......															
*	*	..	*	Angers. . .	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	Doué . . .	..	..	......	..	1	..	..	..	..	..	..	..	..	1				
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	1			
*	*	*?	*	Angers. . .	..	..	......															
..	..	..	..	......	..	..	......	3	3	1	1	3	3	2	2	..	1	1	2	2	1	1
*	*	*	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes Belgium															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Anomia *cont.*	..	..	...	striata ...	...	..	..	..	...
Crania ...	3	3	personata ..	...	Mediterr. ..	*	..	..	...
Orbicula ..	2								
Terebratula .	15	18	vitrea ...	...	Mediterr. ...	*	*?	..	...
——— .	..	..	caput serpentis	...	ibid. ...	*	..	..	...
——— .	..	..	truncata ..	...	ibid. ...	*	..	..	...
——— .	..	..	...	ampulla ..	...	*	*	..	Morea ..
Thecidea ..	1	1	Mediterranea	...	Mediterr. ...	*	..	..	...
Lingula ..	1								
Hyalæa ..	10	2	...	...	...	..	..	..	...
Cleodora ..	14	3	lanceolata .	...	African Ocean	..	*	..	Asti ...
———. .	..	..	...	strangulata .	...	..	..	..	...
———. .	..	..	...	new species .	...	..	*	..	...
Limacina .	1								
Cymbulia .	1								
Chitonellus .	1								
Chiton ...	35	1	...	...	...	..	..	..	...
Dentalium .	23	34	elephantinum	...	Indies, Mediterr.	..	*	..	Morea ..
——— .	..	..	...	sexangulare.	...	*	*	..	ibid. ..
——— .	..	..	dentalis ..	...	Mediterr. ...	*	*	..	Maryland.
——— .	..	..	...	fossile ...	...	*	*	..	...
——— .	..	..	novem costatum	...	European Ocean	*	..	..	...
——— .	..	..	...	pseudo-entalis	...	..	..	..	...
——— .	..	..	entalis ...	...	European Ocean	*	*	*?	Morea ..
——— .	..	..	...	incertum ..	...	..	..	..	...
——— .	..	..	eburneum .	...	Indian Seas .	..	..	..	...
——— .	..	..	fissura ...	...	ibid. ...	..	..	..	...
——— .	..	..	...	coarctatum .	...	..	*	..	...
——— .	..	..	strangulatum	...	Mediterr. ...	*	*	..	Morea ..
——— .	..	..	...	Bouei ...	...	..	*	..	...
Patella. .	104	10	equalis ...	...	European Ocean	..	..	*	...
Siphonaria .	21	3	...	...	...	..	..	..	...
Umbrella. .	2	1	Mediterranea	...	Mediterr. ...	*	..	..	...
Parmophorus	2	2	...	...	...	..	..	..	...
Emarginula.	7	11	fissura ...	...	Europ. Oc. Medt.	..	..	*	...
Fissurella. .	33	8	Græca ...	...	Europ. Oc. Ind.	*	*	..	...
———. .	..	..	costaria ..	...	ibid. ibid. .	*	..	*	...
———. .	..	..	neglecta ..	...	Mediterr. ...	*	*	..	...
———. .	..	..	...	mitis ...	...	..	*	..	...
Pileopsis ..	7	6	Ungarica. .	...	European Ocean	*	*	*	...

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	......	*	*	......	3	3	1	1	3	3	2	2	..	1	1	2	2	1	1
..	..	..	..	......	..	..	......	1	..	..	..	1	..	..	..	..	..	1				
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	4	7	1	..	..	..	..	..	..	..	1	4	..	1	
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	1														
..	..	..	..	......	..	..	......	..	..	..	..	..	1	..	1							
..	..	..	..	......	..	..	......															
*	..	..	..	Baden . . .	..	..	......	..	2	..	1	..	1									
*	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	Baden . . .	..	..	......															
..	..	..	..	ibid. . . .	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	*	..	..	......	..	..	......															
*	*	..	..	......	*	..	......															
*	..	..	..	Baden . . .	*	..	Valognes.	7	10	2	4	3	7	3	..	..	..	1	14	3	2	
*	..	..	..	......	*	..	......															
..	..	..	..	......	*	..	......															
..	..	..	..	......	*	..	......															
*	..	..	..	......	*	..	......															
*	..	..	..	Moravia . .	*	*	......															
..	..	..	..	Baden . . .	..	..	......															
..	..	..	..	......	..	..	......	..	..	1	..	..	..	..	1	..	..	..	5	1	2	
..	..	..	..	......	..	..	......	..	.	..	..	..	2	..	..	..	..	..	..	..	1	
..	..	..	..	......	..	..	......	1														
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	2			
..	*	..	..	Angers. . .	..	..	......	..	..	2	..	..	..	3	..	..	..	3	5	..	2	
*	..	..	..	......	*	..	......															
..	..	..	..	......	*	..	......	3	3	1	..	..	2	2	..	..	..	2	4			
..	*	..	..	Angers. . .	..	..	......															
..	*	..	..	......	..	..	......															
*	*	..	..	Baden . . .	..	..	......	1	2	1	1	..	2	1	..	..	..	..	3			

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Hipponyx	6	12	new species	......	European Ocean	*	*	..	......
———	..	..	......	cornucopiæ	......	..	..	..	......
Crepidula	14	3	sandalina	......	European Ocean New Zealand	*	*	..	......
———	..	..	gibbosa	......	Medit. Indies	..	..	..	......
Calyptræa	19	15	Sinensis	......	European Ocean	*	*	..	Morea
———	..	..	muricata	......	ibid.	*	*	..	ibid.
———	..	..	squamula	......	Mediterr.	*	..	..	......
———	..	..	......	trochiformis	......	..	..	..	......
———	..	..	......	deformis	......	..	..	..	......
Bullæa	2	2	......	......	......	..	..	..	......
Bulla	26	23	lignaria	......	European Ocean	*	*	*	......
———	..	..	ampulla	......	ibid. and Indies	*	*	..	......
———	..	..	......	cylindrica	......	..	..	..	......
———	..	..	......	ovulata	......	..	..	..	......
———	..	..	......	angistoma	......	..	..	..	......
———	..	..	......	striatella	......	..	..	..	......
———	..	..	......	clathrata	......	..	..	..	......
———	..	..	......	cylindroides	......	..	..	..	......
———	..	..	......	Lajonkairiana	......	..	..	..	......
Dolabella	10								
Testacella	2								
Vitrina	5								
Helix	325	35	aspersa ? var.	......	Temperate and Southern Europe	*	..	..	Teneriffe
———	..	..	algira	......	ibid.	..	..	..	Cette, Nice
———	..	..	cespitum	......	Europe	..	*	..	ibid. ibid.
———	..	..	nemoralis	......	ibid.	..	..	..	Quercy
———	..	..	......	Ramondi	......	..	..	..	......
———	..	..	cornea	......	Southern Europe	..	..	..	Nice (osseous)
———	..	..	pisana	......	ibid.	..	..	..	ibid. (osseous)
———	..	..	lapicida	......	Europe	..	..	..	ibid. (osseous)
———	..	..	vermiculata	......	Southern Europe	..	..	..	ibid. (osseous)
———	..	..	cælatura	......	Bourbon	..	*	..	......
Anostoma	2								
Helicina	17	1	......	......	......	..	..	..	......
Pupa	95	3	cinerea	......	Temp. Europe	..	..	..	Nice
———	..	..	muscorum	......	ibid.	..	..	..	Puy-de-Dôme
Clausilia	52	2	......	......	......	..	..	..	......
Bulimus	83	3	......	......	......	..	..	..	......
Achatina	53	3	bulloides	......	Indies	..	*	..	......
Succinea	10								
Auricula	17	18	......	......	......	..	..	..	......

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
*	*	*	..	. . . . . .	..	..	. . . . . .	1	1	1	..	1	1	..	..	..	..	..	8	..	4	1
..	..	..	..	. . . . . .	*	*?	Belgium															
*	*	..	*	Moravia . .	..	..	. . . . . .	1	1	..	1	2	1	..	..	..	1	..	1			
..	*	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	*	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	3	2	1	..	5	4	2	..	..	..	..	4	2	3	
..	..	..	..	. . . . . .	*	*	Valognes .															
*	*	..	*	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	1	..	..	..	..	..	..	..	..	..	1			
*	*	*	..	Angers . . .	*	..	Valognes .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	Valognes .															
*	..	..	..	. . . . . .	*	*	. . . . . .															
*	..	..	..	. . . . . .	*	..	. . . . . .	3	2	1	1	3	7	2	2	..	1	..	14	5	6	
..	..	..	..	. . . . . .	*	..	Castel-gomberto															
*	..	*	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .															
*	..	..	*	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	Auvergne .															
..	..	..	..	. . . . . .	..	..	. . . . . .	1	1	..	..	..	3	5	..	1	..	..	6	..	..	1
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	1	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	1	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .	..	1	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..		..	1	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .	..	1	1	..	2	..	6	..	..	..	..	7			

GENERA.	No. of Species. Living.	No. of Species. Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subapp.	English Crag.	Various Localities.
Pedipes	3	7		ringens					
——			buccinea		Mediterr.	*	*	*	
Scarabæus	3		imbrium		Amboyna		*		
Cyclostoma	49	6	elegans		Europe				Nice.
Ancylus	4	3		elegans					
Planorbis	23	26	corneus		Temp. Europe				
——				rotundatus					
——			marginatus		Europe		*		Tols, Bavari
——			carinatus		ibid.		*		ibid. ibid. Cett
——				cornu					
——				lens					
——			spirorbis		Europe				Nice.
——			nitidus		ibid.				Quercy.
Physa	9	1							
Limnea	15	27	peregra		Europe		*		Lauzerte
——			auricularis		ibid.		*		ibid.
——			rivalis		ibid.				Agen
——				longiscata					
——				inflata					
——				cornea					
——			palustris		Europe				
Melania	34	25	inquinata		Philippine Isles				
——				lactea					
——				nitida					
——			inflexa		Mediterr.		*		
——				costellata					
——			Cambessedesii		Mediterr.	*	*		
——			new species		Lakes of Como and Geneva				
Rissoa	23	22	lactea		Mediterr.	*			
——			cochlearella		Indian Ocean		*		
Pirena	3	2							
Melanopsis	10	11	buccinoidea		Asia, Spain, Greece		*		Greece.
——			Dufourei		Alicant				
——			costata		Asia		*		Greece.
——			nodosa		Spain, &c.		*		
——			acicularis		Laybach				
——			incerta		Asia, Greece				Abydos.
Valvata	4	1	piscinalis		Europe				
Paludina	25	41	achatina		ibid.		*	*	
——				lenta					
——			unicolor		Asia.				

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	. . . . . .	*	..	Valognes .															
..	*	..	*	Angers, Baden	..	..	:	1	3	1	1	1	2	1	1	..	1	1	1	..	1	
..	..	..	..	. . . . . .	*	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	6			
..	..	..	..	. . . . . .	..	*	Auvergne, Cantal	..	..	..	..	..	..	..	..	..	..	..	2	1		
..	..	..	..	. . . . . .	*?	..	. . . . . .															
*	*	..	..	. . . . . .	*	..	Auvergne.															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	..	Auvergne.	..	2	..	2	2	1	1	..	..	..	..	13	7		
..	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	. . . . . .	*	*	Auvergne.	..	2	..	1	1	1	..	..	..	1	..	15	3		
..	..	..	..	. . . . . .	*	..	ibid. . .															
..	..	..	..	. . . . . .	*	..	ibid. . .															
..	..	..	..	. . . . . .	*?	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	Abbeville.															
..	..	..	..	Ronca . .	*	..	Tours, Valognes .															
*	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	..	Angers . .	..	..	. . . . . .	1	2	..	..	2	3	..	1	1	..	2	17	4	7	
*	..	*	..	. . . . . .	*	..	Valognes .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	Arapatack	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	1	1	..	..	3	9	..	..	..	3	4	5	..	2	
*	..	..	..	Angers. . .	*	..	Valognes .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	1	1		
..	..	..	..	. . . . . .	*	*	. . . . . .															
*	..	..	..	Hungary . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	..	. . . . . .	..	3	..	2	1	1	..	..	..	1	..	5	3		
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	*	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	*	..	..	. . . . . .	*?	..	. . . . . .	..	..	..	..	..	..	1	..	..	..	..	1			
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .	..	6	2	2	2	4	..	..	..	1	..	17	3		
..	..	..	..	. . . . . .	*	..	Alsace . .															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Paludina, *cont.*	..	..	impura. . .	. . . . . .	Europe. . . .	..	*		
Ampullaria .	24	14	. . . . .	Willemetii .	. . . .	..	..	..	. . . . . .
Pileolus . .	..	2	. . . . .	. . . . . .	. . . .	..	..	..	. . . . . .
Navicella. .	2								
Neritina . .	60	17	fluviatilis . .	. . . . . .	Europe. . . .	..	*	..	. . . . . .
———. . .	..	..	. . . . .	conoidea . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	globulus . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	new species .	. . . .	..	..	..	. . . . . .
Nerita . . .	18	16	. . . . .	Caronis . .	. . . .	..	..	..	. . . . . .
——— . .	..	..	. . . . .	tricarinata .	. . . .	..	..	..	. . . . . .
——— . .	..	..	. . . . .	mammaria .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	new species .	. . . .	..	..	..	. . . . . .
Natica . . .	56	41	millepunctata	. . . . .	European Ocean	*	*	*	Morea, Perpignan
———. . .	..	..	Guillemini .	. . . . .	Mediterr. . . .	*	..	..	. . . . . .
———. . .	..	..	canrena . .	. . . . .	European Ocean	*	*	*	Morea, Perpignan
———. . .	..	..	Valenciennesii	. . . .	Mediterr. English Channel	*	..	*	. . . . . .
———. . .	..	..	Dilwynii . .	. . . . .	ibid. and Senegal	*	*	..	. . . . . .
———. . .	..	..	glaucina . .	. . . . .	Ind. & Europ. Oc.	*	*	*	Morea, Perpignan
———. . .	..	..	monilifera .	. . . . .	English Channel	..	..	*	. . . . . .
———. . .	..	..	. . . . .	new species .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	sigaretina. .	. . . .	..	..	..	. . . . . .
———. . .	..	..	mamilla . .	. . . . .	Indian Ocean .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	new species .	. . . .	..	..	..	. . . . . .
———. . .	..	..	zebra . . .	. . . .	Indian Ocean, Senegal	..	*	..	. . . . . .
———. . .	..	..	. . . . .	epiglottina .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	mutabilis . .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	glaucinoides.	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	intermedia .	. . . .	..	..	..	. . . . . .
———. . .	..	..	. . . . .	new species .	. . . .	..	..	..	. . . . . .
Sigaretus. .	11	4	. . . . .	canaliculatus	. . . .	..	..	..	. . . . . .
———. .	..	..	. . . . .	lævigatus . .	. . . .	..	..	..	. . . . . .
———. .	..	..	depressus. .	. . . .	Seas of the Molucca Islands	..	*	..	. . . . . .
Stomatella .	6	1	locality unknown of fossil species						
Stomatia . .	2								
Haliotis . .	29	1	tuberculata .	. . . .	European and African Ocean	*	..	..	. . . . . .
Tornatella .	7	11	fasciata . .	. . . . .	European Ocean	..	*	*	. . . . . .
———. .	..	..	. . . . .	inflata . . .	. . . .	..	*	..	. . . . . .
———. .	..	..	. . . . .	semisulcata .	. . . .	..	*	..	. . . . . .
Pyramidella.	11	8	. . . . .	terebellata .	. . . .	..	..	..	. . . . . .
——— . .	..	..	. . . . .	acicula . . .	. . . .	..	..	..	. . . . . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	......	*	..	Castelgomberto	..	1	..	..	..	2	..	..	1	..	..	7	1	1	
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	..	1	..	1
..	..	..	..	......	..	..	......															
..	..	*	..	Ronca . .	*	..	......															
..	..	..	..	......	*	*	......	..	3	..	..	1	4	..	1	..	1	..	9	3		
*	..	..	*	Podolia . .	..	..	......															
*	*	*	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes.	..	..	..	1	1	4	5	1	1	..	1	4	3	3	
..	..	..	..	......	*	*	......															
*	*	..	..	......	..	..	......															
*	*	*	*	......	..	..	......															
..	..	..	..	Transylvania	..	..	......															
*	*	..	*	Volhynia, Baden, Moravia	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	*	*	*	Ronca, Angers, Transylvania	..	..	......															
..	..	..	..	......	*?	*?	Valognes.															
*	*	..	..	......	..	..	......															
*?	..	..	..	......	*	..	Castelgomberto	6	8	6	4	8	9	7	5	5	..	2	16	6	9	1
..	..	*	..	......	..	..	......															
*	..	*	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes Belgium															
..	..	..	..	Ronca. . .	*	*	ibid. . . .															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	..	Castelgomberto															
*	*	..	..	......	..	..	......															
*	..	..	..	......	*	*	......															
*	..	..	..	......	*	..	......	..	1	..	..	1	2	1	..	..	..	..	2	1	1	
*	*	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	1														
..	..	..	..	......	..	..	......															
*	..	..	..	......	*	..	......	..	3	1	..	5	8	..	..	..	..	..	3	2		
*	..	..	..	......	..	..	......															
*	*	..	..	Angers . .	*	..	Valognes .	..	..	..	..	4	3	1	..	..	..	1	5	..	3	
..	..	..	..	......	*	..	ibid. . .															

GENERA.	No. of Species. Living.	Fossil (tert.)	Species found both living and fossil (tertiary.)	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
New Genus. Bulimus Terebellatus, Lam.		1		terebellatus			*		
Vermetus	8	1							
Siliquaria	4	6	anguina		Mediterr. Indian Ocean.		*		
Magilus	2								
Scalaria	14	22	communis		European Ocean	*		*?	
———			pseudoscalaris		Mediterr.	*	*		
———			tenuicostata		ibid.	*			
———			lamellosa		Mediterr. Indian Ocean		*		
———			varicosa		Unknown		*		
———				crassicostata			*		
———				multilamella					
———				cancellata			*		
———				subulata				*	
Delphinula	7	12		marginata					
Solarium	12	16	variegatum		Mediterr. Indies	*	*		
———			carocollatum		Mediterr.		*		
———			pseudo perspectivum		ibid.		*		
———				umbrosum			*		
———				new species					
———				patulum					
———				plicatulum					
———				plicatum					
Omalaxon		5							
Rotella	4								
Trochus	103	70	magus		European Ocean, Senegal	*	*		Ischia
———			fagus		Mediterr.	*			
———			cingulatus		Adriatic	*	*		
———			agglutinans		Mediterr. East Ind. America, &c.	*	*		
———			Adansoni		Mediterr.	*			Ischia
———			conulus		European Ocean	*	*	*?	
———			cinerarius		ibid.	*			
———			conuloides		ibid.	*			
———			Matoni		ibid.	*			
———			zizyphinus		ibid.	*		*	
———				infundibulum					
———			strigosus		Unknown		*		
———				patulus			*		Morea
———				crenulatus		*			
———			obliquatus		Mediterr.	*			
———				monilifer					

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
*	*	..	*	Angers, Baden	*	..	Valognes . .	..	1	..	1	1	1	1	..	..	1	1	1	..	1	
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	1				
*	*	..	..	Angers. . .	..	..	. . . . . .	..	1	..	..	..	1	1	..	..	..	1	5	..	3	
*?	*?	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .	2	8	3	1	2	8	1	..	..	..	..	7	4		
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	*	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	*	..	Valognes . .	..	1	..	..	1	2	1	1	..	..	..	8	5		
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	*	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	Angers. . .	..	..	. . . . . .	1	6	..	..	2	3	1	1	..	..	1	7	3	3	
..	..	..	..	. . . . . .	*	*	Valognes .															
..	..	..	..	. . . . . .	*	*	ibid. . .															
..	..	..	..	. . . . . .	*	*	ibid. . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	5			
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	Volhynia ? .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	Valognes, Castelgomberto															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	11	13	2	1	6	13	11	3	2	1	9	18	4	5	
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	*	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	*	*	Angers, Volhynia, Transylvania.	..	..	. . . . . .															
..	*	..	..	Angers. . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Trochus, *cont.*	..	..	.....	boscianus . .	....	..	..	..	......
——— . .	..	..	.....	carinatus . .	....	..	*	..	......
——— . .	..	..	.....	new species .	....	..	..	..	......
Pleurotomaria	..	1	.....	.....	....	..	..	..	......
Monodonta .	42	8	.....	Pharaonis .	....	..	*	..	......
Turbo . . .	56	34	rugosus . .	.....	Mediterr. . . .	*	*	..	......
———. . .	..	..	new species .	.....	Indian Ocean .	*	*	..	......
———. . .	..	..	costatus . .	.....	Mediterr. . . .	*	*	..	......
———. . .	..	..	.....	sculptus . .	....	..	..	..	......
Littorina . .	24	10	littorea . .	....	Seas of Northern Europe	..	..	*	......
———. .	..	..	.....	new species .	....	..	..	..	......
———. .	..	..	striata . . .	.....	European Ocean	..	..	*	......
Planaxis . .	4	5	.....	.....	....	..	..	..	......
Phasianella .	9	4	pullus . . .	.....	European Ocean	..	..	..	......
Turritella . .	24	45	terebra . . .	.....	ibid.	*	*	..	......
———. .	..	..	new species .	.....	Senegal . . .	..	..	..	......
———. .	..	..	Ligar. . . .	.....	ibid.	..	..	..	......
———. .	..	..	.....	terebellata .	....	..	..	..	......
———. .	..	..	.....	imbricataria.	....	..	..	..	......
———. .	..	..	new species .	.....	Mediterr. . . .	..	..	*	......
———. .	..	..	.....	Desmarestina	....	..	*	..	......
———. .	..	..	.....	spirata . . .	....	..	*	..	......
———. .	..	..	.....	subangulata.	....	*	*	..	......
———. .	..	..	.....	vermicularis.	....	..	*	..	......
———. .	..	..	.....	tornata . . .	....	*	*	..	......
———. .	..	..	.....	turris . . .	....	..	..	..	......
———. .	..	..	.....	granulosa. .	....	..	..	..	......
Proto. . . .	2	4	.....	cathedralis .	....	..	..	..	......
Cerithium .	87	220	vulgatum. .	....	European Ocean, Senegal	*	*	..	Morea, Ischia
——— .	..	..	Latreillei . .	.....	Mediterr. . . .	*	*	..	Ischia . . .
——— .	..	..	doliolum . .	.....	ibid.	..	*	..	......
——— .	..	..	giganteum .	.....	New Holland ??	..	..	..	......
——— .	..	..	.....	plicatum . .	....	..	..	..	......
——— .	..	..	.....	hexagonum .	....	..	..	..	......
——— .	..	..	.....	pleurotomoides.	....	..	..	..	......
——— .	..	..	.....	cinctum . .	....	..	..	..	......
——— .	..	..	.....	Cornucopiæ .	....	..	..	..	......
——— .	..	..	.....	geminatum .	....	..	..	..	......
——— .	..	..	.....	ventricosum .	....	..	..	..	......
——— .	..	..	.....	Lamarckii .	....	..	..	..	......
——— .	..	..	.....	Cordieri . .	....	..	..	..	......

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
*	*	..	..	. . . . . .	..	..	. . . . . .															
..	..	*	..	. . . . . .	..	..	. . . . . .	11	13	2	1	6	13	11	3	2	1	9	18	4	5	
*	*	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	1			
*	*	..	..	Angers . .	..	..	. . . . . .	..	2	..	..	1	1	3	1	..	..	1	1	..	1	
..	..	..	*	Moravia . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	Angers . .	..	..	. . . . . .	3	5	..	..	5	3	3	4	2	1	2	16	2	5	
..	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	. . . . . .	..	..	. . . . . .	..	..	2	1	1	3	1	..	..	..	1	3	..	1	
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	1	..	..	..	..	..	4			
*	..	..	..	. . . . . .	*	..	. . . . . .	..	..	..	..	1	1	..	..	..	..	..	2	..	2	
..	*	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	Valognes .															
..	..	*??	..	. . . . . .	*	*	id. Belgium															
*?	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .	3	19	3	5	8	6	7	5	2	6	1	17	4	6	1
*	*	..	..	. . . . . .	..	..	. . . . . .															
..	*	..	..	Angers . .	..	..	. . . . . .															
*	*	..	..	Transylvania	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	*	Cracovia, Volhynia	..	..	. . . . . .															
..	..	..	..	Ronca . . .	*	..	. . . . . .															
*	*	*	..	. . . . . .	..	..	. . . . . .	..	..	..	..	2	3	2	1	1						
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .															
*	..	*	*	Montpellier, Podolia	*	..	Klein-spaunen, Mayence															
..	..	*	..	Ronca . . .	*	..																
..	..	..	..	. . . . . .	*	*	Valognes .	4	14	2	3	27	19	11	8	7	6	9	137	11	53	4
..	..	..	..	. . . . . .	*	*	ibid. . .															
..	..	..	..	. . . . . .	..	*	ibid. Castel-gomberto															
..	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	..	. . . . . .	*	..	Auvergne .															
..	..	..	..	. . . . . .	*	*	. . . . . .															

GENERA.	No. of Species		Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD.			
	Living.	Fossil (tert.)				Sicily.	Italy, Subap.	English Crag.	Various Localities.
Cerithium, *cont*				tricinctum			*	*?	
———				margaritaceum			*		
———				corrugatum			*		
———				inconstans					
———				papaveraceum					
———				crenatum			*		
———				pictum					
———			alucaster		Mediterr.		*		
———				multisulcatum					
———				new species					
———			granulosum		Mediterr.	*	*		
———				inversum					
———			bicinctum		Mediterr.	*	*		
———				new species					
———				new species					
———				salmo					
———				pupæforme					
Triforis	3	2							
Pleurotoma	71	156		intorta			*		
———				cataphracta			*		
———				rustica			*		
———				oblonga			*		
———				new species			*		
———				new species			*		
———				interrupta			*		
———				rotata			*		
———				reticulata			*		
———			Cordieri		Mediterr.	*			
———			caumarmondi		ibid.	*			
———			vulpecula		ibid.	*	*		
———			craticulata		ibid.	*			
———			new species		ibid.	*			
———				tuberculosa					
———				denticula					
———				Borsoni					
———				new species			*		
———				turella			*		
———				pustulosa			*		
———				plicata					
———				new species					
———				new species					

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
*	*	*	..	......	..	..	......															
*	..	*	*	Weissenau .	..	..	......															
*	*	*	..	......	..	..	......															
*	..	..	*	Austria . .	..	..	......															
*	*	..	..	Montpellier .	..	..	......															
*	*	..	..	Volhynia, Transylvania	..	..	......															
*	*	..	*	Podolia, Hungary	..	..	......															
*	..	..	..	......	..	..	......															
*	*	*	..	Montpellier .	..	..	......	4	14	2	3	27	19	11	8	7	6	9	137	11	53	4
..	*	..	..	Baden . . .	..	..	......															
*	..	..	..	......	..	..	......															
..	..	..	..	Angers . .	*	..	Valognes.															
..	..	..	..	......	..	..	......															
*	..	..	..	Angers . .	..	..	......															
*	*	..	..	......	..	..	......															
*	*	..	..	Moravia . .	..	..	......															
*	..	..	*	Volhynia .	..	..	......															
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	2			
*	..	..	..	......	..	..	......															
*	..	..	..	......	..	*?	......															
*?	*?	..	..	......	..	..	......															
*	*	..	*	......	..	..	......															
*	*	..	..	......	..	..	......															
..	..	..	*	Angers . .	..	..	......															
..	..	..	*	......	..	..	......															
..	..	..	..	......	..	..	......															
*	*	*	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	5	33	..	12	30	22	15	1	..	5	17	41	10	12	3
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	*	..	*	Cracovia . .	..	..	......															
*	..	..	..	Baden . .	..	..	......															
*	*	..	*	ibid. . . .	..	..	......															
*	..	..	..	......	..	..	......															
*	*	..	*	......	..	..	......															
*	..	..	..	......	..	..	......															
*?	..	..	..	Angers . .	*	..	......															
..	*	..	..	ibid. . . .	..	..	......															
..	..	..	..	ibid. . . .	*	..	......															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Pleurotoma *continued*				dentata					
———				clavicularis					
———				multinoda					
———				lineolata					
Turbinella	32	3							
Cancellaria	13	42	cancellata		Mediterr. Senegal	*	*		
———				varicosa			*		
———				contorta			*		
———				hirta			*		
———				evulsa					
———				Lyra			*		
Fasciolaria	7	5		new species					
Fusus	67	111	craticulatus		Mediterr.	*			
———			rostratus		ibid.	*			
———			strigosus		ibid.	*			
———			lignarius		ibid.	*	*		
———			sinistrorsus		Unknown	*			
———			Tarentinus		Mediterr.	*			
———			antiquus		Seas of Northern Europe			*	
———			brevicauda		ibid.			*	
———			carinatus		ibid.			*	
———			despectus		ibid.			*?	
———			Peruvianus		Unknown, Peru??			*	
———				crispus		*	*		
———				mitræformis			*		
———				subulatus			*		
———				abreviatus					
———				Burdigalensis					
———				new species					
———				bulbiformis					
———				Noæ					
———				scalaris					
———				acicularis					
———				ficulneus					
———				excisus					
———				polygonus					
———				minax					
———				costulatus					
———				subcarinatus					
———				longævus					
———				new species					

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	Angers, Ronca	*	*	Valognes .															
..	..	..	..	......	*	*	ibid. . .															
..	..	..	..	......	*	*	ibid. . .	5	33	..	12	30	22	15	1	..	5	17	41	10	12	3
..	..	..	..	......	*	*	ibid. . .															
..	..	..	..	......	..	..	......	..	1	..	..	1	2									
*	*?	..	*	......	..	..	......															
..	..	..	*	......	..	..	......															
*	..	..	..	Moravia . .	..	..	......	1	16	..	3	12	5	5	..	..	2	2	5	3	3	
*	..	..	..	......	..	..	......															
..	..	..	..	......	*	*	......															
..	..	..	..	Baden . .	..	..	......															
*	*	..	*	......	..	..	......	..	1	..	..	2	3	1	..	..	1	..	1			
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*	*?	*	..	......	..	..	......	10	13	8	3	11	11	10	4	3	2	4	42	14	18	
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..	..	..	..	Ronca . . .	*	*?	......															
..	..	..	..	......	*	*	......															
..	..	..	..	Ronca . . .	*	..	......															
..	..	..	..	ibid. . . .	*	..	......															
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GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Fusus, *cont.*	..	..	. . . . . .	new species	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	new species	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	new species	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	sublavatus	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	. . . . . .	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	. . . . . .	. . . . . .	..	..	..	. . . . . .
Pyrula	31	21	reticulata	. . . . . .	Indian Ocean	..	*	..	. . . . . .
———	..	..	ficus	. . . . . .	ibid.	..	*	..	. . . . . .
———	..	..	melongena	. . . . . .	ibid. and Senegal	..	..	..	. . . . . .
———	..	..	spirillus	. . . . . .	ibid. ibid.	..	..	..	. . . . . .
———	..	..	. . . . . .	clava	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	ficoides	. . . . . .	..	*	..	. . . . . .
———	..	..	. . . . . .	lævigata	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	subcarinata	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	elegans	. . . . . .	..	..	..	. . . . . .
Struthiolaria	2	1?	. . . . . .	. . . . . .	. . . . . .	..	..	..	. . . . . .
Ranella	19	8	gigantea	. . . . . .	Mediterr.	*	*	..	. . . . . .
———	..	..	granulata	. . . . . .	Indian Ocean? Senegal?	..	..	..	. . . . . .
———	..	..	pygmæa	. . . . . .	European Ocean	..	..	..	. . . . . .
———	..	..	tuberosa	. . . . . .	Isle of France	..	*	..	. . . . . .
———	..	..	. . . . . .	lævigata	. . . . . .	..	*	..	Perpignan, Morea
Murex	75	89	cornutus	. . . . . .	Senegal	..	*	..	. . . . . .
———	..	..	Brandaris	. . . . . .	Mediterr.	*	*	..	Toulon, Perpignan, Morea
———	..	..	trunculus	. . . . . .	ibid. & Indian Oc. Senegal	*	*	..	Morea
———	..	..	erinaceus	. . . . . .	Europ. Oc. Medit.	*	*	..	Perpignan, Morea
———	..	..	tripterus	. . . . . .	Indian Ocean	..	*?	..	. . . . . .
———	..	..	cristatus	. . . . . .	Mediterr.	*	*	..	. . . . . .
———	..	..	fistulosus	. . . . . .	ibid.	*	*	..	. . . . . .
———	..	..	tubifer	. . . . . .	Unknown	..	*	..	. . . . . .
———	..	..	. . . . . .	rectispina	. . . . . .	..	*	..	. . . . . .
———	..	..	. . . . . .	suberinaceus	. . . . . .	..	..	..	. . . . . .
———	..	..	new species	. . . . . .	Senegal	..	..	..	. . . . . .
———	..	..	elongatus	. . . . . .	ibid. and Indian Ocean	..	..	..	. . . . . .
———	..	..	angularis	. . . . . .	Senegal	..	..	..	. . . . . .
———	..	..	saxatilis, var.	. . . . . .	ibid.	..	..	..	. . . . . .
———	..	..	new species	. . . . . .	Sicily	..	..	..	. . . . . .
———	..	..	. . . . . .	polymorphus	. . . . . .	..	*	..	. . . . . .
———	..	..	. . . . . .	contabulatus	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	tricarinatus	. . . . . .	..	..	..	. . . . . .
———	..	..	. . . . . .	tripterus	. . . . . .	..	..	..	. . . . . .
———	..	..	Lasseignei	. . . . . .	Mediterr.	*	*	..	. . . . . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
*	..	*	..	......	..	..	......															
*	..	..	*	......	..	..	......															
*	..	..	*	......	..	..	......	10	13	8	3	11	11	10	4	3	2	4	42	14	18	
..	*	..	..	Moravia ..	..	..	......															
*	..	..	..	ibid. ..	..	..	......															
..	..	..	..	......	*	*	......															
*	*	*	..	Angers. ..	..	..	......															
*	..	*	..	......	..	..	......															
*	*	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
*	..	..	..	......	*?	..	......	..	3	..	1	7	6	2	1	..	..	..	10	3	3	
*	..	..	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes .															
..	..	..	..	......	*	*	ibid. ..															
..	..	..	..	......	*	*	......															
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	1			
*	..	..	..	......	..	..	......															
*?	..	..	..	......	..	..	......	1	4	..	1	5	6	..	2	..	1					
*?	..	..	..	......	..	..	......															
*	..	*	..	......	..	..	......															
*	..	*	*	Baden ..	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	Angers. ..	..	..	......															
*?	*	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
*?	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	..	..	..	Baden ..	..	*	......															
*	*	..	..	......	*	*	......															
*	..	..	..	Baden ..	..	..	......															
*	..	*	..	......	..	..	......	7	20	5	6	15	20	18	3	..	2	9	24	8	9	
*	*	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
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*	..	..	..	......	..	..	......															
..	..	..	..	Angers. ..	*	..	Valognes .															
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*	..	..	..	......	..	..	......															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Murex, *cont.*			new species.		Mediterr.	*			
———				new species					
———				sublavatus					
———				new species					
Triton	43	25	nodiferum		Mediterr. and Indian Ocean	*	*		
———			lampas		Indian Ocean		*?		
———			scrobiculator		Mediterr.		*?		
———			succinctum		ibid., New Holland? Lam.		*		
———			clathratum		Indian Ocean				
———			unifilosum		Mediterr.		*		
———				intermedium			*		
———				cancellinum			*		
———				gibbosum					
———				new species			*		
———				nodularium					
———				viperinum					
Rostellaria	7	8		macroptera					
———				columbella					
———				fissurella					
———			pes pelicani		European Ocean	*	*		Morea, Perpignan
———			pes carbonis		Mediterr.				
———			new species		ibid.		*		
Pterocera	7								
Strombus	45	9	gigas		Indian Ocean & West Indies		*?		
———				new species			*		
———				Bonelli					
———				ornatus					
Cassidaria	7	8	echinophora		Mediterr.	*	*		Morea, Perpignan
———			Thyrrena		ibid.	*	*		
———				new species			*		
———				carinata					
———				cithara					
Cassis	30	15	flammea		Indian and African Oceans				
———			granulosa		Mediterr.		*		
———			crumena		Unknown		*		
———			Saburon		Medit. Senegal	*	*		Morea
———			new species		Unknown				
———			bisulcata		Senegal?		*		
———				cypræformis			*		
Ricinula	14	1		new species					

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	Cracovia .	..	..	. . . . . .															
*	..	..	..	ibid. . .	..	..	. . . . . .	7	20	5	6	15	20	18	3	..	2	9	24	8	9	
*	..	..	..	Baden . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
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*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .	1	8	..	..	3	7	1	2	..	1	1	6	2	5	
*	*	*	*	. . . . . .	..	..	. . . . . .															
*	..	*	..	. . . . . .	..	..	. . . . . .															
..	*	..	*	Cracovia . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	*	*	Valognes .															
..	..	..	..	. . . . . .	*	*	ibid. . . .															
..	..	..	..	. . . . . .	*	*	Belgium .															
..	..	..	..	. . . . . .	*	..	ibid. . .															
..	..	..	..	. . . . . .	*	*	Valognes .															
..	..	..	*	Moravia . .	..	..	. . . . . .	1	2	..	..	3	3	2	1	..	1	..	4	3	2	2
*	*	*	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	. . . . . .	..	..	. . . . . .															
*?	..	..	..	. . . . . .	..	..	. . . . . .															
..	*	..	..	. . . . . .	..	..	. . . . . .															
*	..	*	..	. . . . . .	..	..	. . . . . .	..	2	..	..	1	4	1	1	1	..	..	2	1	1	
..	..	..	..	. . . . . .	*	*	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	*	..	. . . . . .	..	..	. . . . . .	2	2	..	..	..	2	..	1	..	..	..	3	1	1	1
..	..	..	..	. . . . . .	*	*	Valognes Belgium															
*	..	*	..	. . . . . .	..	..	. . . . . .															
*?	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	*	..	. . . . . .	..	..	. . . . . .	1	5	1	2	4	4	..	2	..	1	..	2	1	1	
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	*	Baden . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	*	..	. . . . . .	..	..	. . . . . .	..	..	..	..	1	1	..	1							

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Purpura . .	76	4	hæmastoma.	. . . . . .	Medit., Senegal	. .	*	. .	. . . . . .
———. . .	. .	. .	. . . . . .	new species .	. . . .	. .	. .	. .	. . . . . .
———. . .			. . . . . .	new species . .	. . . .	. .	. .	. .	. . . . . .
Monoceros .	6	1	. . . . . .	. . . . . .	. . . .	. .	. .	. .	. . . . . .
Harpa . . .	8	2	. . . . . .	. . . . . .	. . . .	. .	. .	. .	. . . . . .
Dolium . .	7	1	pomum ? . .	. . . . . .	Indian Ocean .	. .	*?	. .	. . . . . .
Buccinum .	143	95	undatum . .	. . . . . .	European Seas, Senegal	. .	. .	*	. . . . . .
———. .	. .	. .	reticulatum .	. . . . . .	ibid. ibid. .	. .	*	. .	. . . . . .
———. .	. .		maculosum .	. . . . . .	Mediterr. . . .	*	. .	. .	Morea . . .
———. .	. .	. .	mutabile	. . . . . .	ibid.	*	*	. .	Perpignan, Morea
———. .	. .	. .	clathratum .	. . . . . .	Indian Ocean .	. .	*	. .	ibid. . . .
———. .	. .	. .	Neriteum .	. . . . . .	ibid. Medit.	. .	*	. .	Morea . . .
———. .	. .	. .	Desnoyersi .	. . . . . .	Senegal . . .	. .	. .	. .	. . . . . .
———. .	. .	. .	prismaticum	. . . . . .	Mediterr. . . .	*	*	. .	Ischia . .
———. .	. .	. .	asperulum .	. . . . . .	ibid.	*	*	. .	. . . . . .
———. .	. .	. .	musivum. .	. . . . . .	ibid.	*	*	. .	. . . . . .
———. .	. .	. .	inflatum . .	. . . . . .	ibid.	*	*	. .	Perpignan, Morea
———. .	. .	. .	polygonum .	. . . . . .	Unknown . .	. .	*	. .	. . . . . .
———. .	. .	. .	D'Orbignii .	. . . . . .	Mediterr. . . .	*	. .	. .	. . . . . .
———. .	. .	. .	Linnæi . .	. . . . . .	ibid.	. .	*	. .	. . . . . .
———. .	. .	. .	new species .	. . . . . .	Indian Ocean	. .	. .	. .	. . . . . .
———. .	. .	. .	politum . .	. . . . . .	ibid.	. .	. .	. .	. . . . . .
———. .	. .	. .	new species .	. . . . . .	Unknown . .	. .	. .	. .	. . . . . .
———. .	. .	. .	ditto . . .	. . . . . .	Mediterr.. . .	*	. .	. .	. . . . . .
———. .	. .	. .	ditto . . .	. . . . . .	ibid.	*	. .	. .	. . . . . .
———. .	. .	. .	ditto . . .	. . . . . .	Unknown . .	. .	. .	. .	. . . . . .
———. .	. .	. .	. . . . . .	serratum . . .	. . . .	. .	*	. .	Perpignan .
———. .	. .	. .	. . . . . .	baccatum . .	. . . .	. .	. .	. .	. . . . . .
———. .	. .	. .	. . . . . .	new species.	. . . .	. .	. .	. .	. . . . . .
———. .	. .	. .	. . . . . .	tessellatum .	. . . .	. .	*	. .	. . . . . .
———. .	. .	. .	. . . . . .	new species.	. . . .	. .	. .	. .	. . . . . .
———. .	. .	. .	. . . . . .	semistriatum	. . . .	*	*	. .	Perpignan, Morea
———. .	. .	. .	. . . . . .	callosum . . .	. . . .	. .	*	. .	. . . . . .
———. .	. .	. .	. . . . . .	new species.	. . . .	. .	. .	. .	. . . . . .
———. .	. .	. .	. . . . . .	Andrei . .	. . . .	. .	. .	. .	. . . . . .
———. .	. .	. .	. . . . . .	new species.	. . . .	. .	. .	. .	. . . . . .
———. .	. .	. .	. . . . . .	angulatum .	. . . .	. .	*	. .	. . . . . .
———. .	. .	. .	. . . . . .	new species, reticulatum affinis	. . . .	. .	. .	. .	. . . . . .
———. .	. .	. .	. . . . . .	turritum . .	. . . .	. .	. .	. .	. . . . . .
Eburna . .	5	1	. . . . . .	new species .	. . . .	. .	. .	. .	. . . . . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	..	*	..	. . . . . .	..	..	. . . . . .	..	1	..	..	1	2		1	..	1	..	1			
..	*	..	*	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .	..	1													
..	..	..	..	. . . . . .	..	..	. . . . . .	..	..	..	..	..	..	..	..	..	..	..	2			
..	..	..	..	. . . . . .	..	..	. . . . . .	..	1													
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	*	Podolia . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*?	..	..	*?	Volhynia . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	*	. . . . . .	..	..	. . . . . .															
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..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	*	..	. . . . . .	..	..	. . . . . .															
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..	*	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	Angers . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
..	*	..	..	. . . . . .	..	..	. . . . . .	10	27	9	7	21	14	18	3	1	8	6	9	4	5	2
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	. . . . . .	..	..	. . . . . .															
..	*?	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	*	. . . . . .	..	..	. . . . . .															
*	..	..	*	Podolia . .	..	..	. . . . . .															
*	*	..	..	. . . . . .	..	..	. . . . . .															
*	..	..	..	. . . . . .	..	..	. . . . . .															
*	*	..	..	. . . . . .	..	..	. . . . . .															
..	..	..	..	Baden, Moravia	..	..	. . . . . .															
*	*	..	*	. . . . . .	..	..	. . . . . .															
*	..	..	*	. . . . . .	..	..	. . . . . .															
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*	*	..	..	. . . . . .	..	..	. . . . . .															
*	..	*	..	Ronca . . .	..	..	. . . . . .	..	..	..	..	1	1	..	1	1						

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subap.	English Crag.	Various Localities.
Terebra	44	16	Faval		Senegal, Indian Ocean		*		Perpignan, Morea
———			new species		Unknown				
———			strigilata		Ind. Oc. Senegal		*		
———			pertusa		Unknown				
———			new species		ibid.		*		
———				striata					
———				plicatula					
Columbella	33	4		new species					
Mitra	112	66		scrobiculata			*		Morea, Perpignan
———				fusiformis			*		
———			lutescens		Mediterr.	*			
———			cornea		ibid.		*		
———				incognita					
———				columbellata					
———				graniformis					
———				cupressina			*		
Voluta	66	32	Lamberti		Unknown South Seas ?			*	
———				papillaris					
———				magorum			*		
———				rarispina					
———				spinosa					
———				costaria					
———				crassicosta					
———				athleta					
———				ambigua					
———				digitalina					
———				crenulata					
Marginella	48	17	cypræola		Mediterr.	*	*		
———			miliacea		Senegal				
———				eburnea					
———			monilis		Senegal		*?		
Volvaria	1	2		bulloides					
———				acutiuscula					
Ovula	18	6	spelta		Mediterr.				
———			birostris		Indian Ocean		*		
———			new species		Mediterr.	*			
Cypræa	135	19	lurida		ibid.	*	*		
———			rufa		ibid.	*	*		
———			annulus		African Ocean				
———			coccinella		European Ocean	*	*	*	
———			new species		Sicily		*		

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
*	*	..	*	Baden . . .	..	..	......															
*	..	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
*	..	..	..	......	..	..	......	..	5	4	10	7	2	3	..	..	3	..	1	1	1	
*	..	..	..	......	..	..	......															
*	*	..	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes .															
*	*	..	*	Angers . .	..	..	......	..	1	..	..	..	..	2	..	..	1	2				
*	..	..	..	Baden . . .	..	..	......															
..	*	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	*	..	..	......	..	..	......	1	13	..	2	4	6	15	..	..	..	8	24	3	15	
*	*	..	..	......	..	..	......															
..	..	..	..	......	*	*?	Valognes .															
..	..	..	*	......	..	..	......															
*	*	..	..	Angers . .	..	..	......															
*	..	*	..	......	..	..	......															
..	..	*	..	......	..	..	......															
*	*	*	*	......	..	..	......															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	Valognes .	..	2	1	..	4	4	2	4	1	1	..	24	8	7	3
*	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	Valognes .															
..	..	*?	..	......	*	*	......															
*	*	..	..	Angers . .	..	..	......															
*	*	..	..	ibid. . .	..	..	......															
..	..	*	..	......	*	..	Valognes .	1	5	..	..	2	2	2	1	1	..	2	9	..	4	
..	..	..	..	......	..	..	......															
..	..	..	..	......	*	..	Valognes .	..	..	..	..	..	..	..	..	..	..	..	2	1	1	
..	..	..	..	......	*	*	......															
..	*	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	..	2	..	..	..	..	2	..	..	..	..	2			
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	..	*	..	Transylvania	..	..	......	3	6	3	..	4	8	5	6	..	..	3	4	1	2	
*?	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	PLIOCENE PERIOD. Italy, Subap.	PLIOCENE PERIOD. English Crag.	PLIOCENE PERIOD. Various Localities.
Cypræa, *cont.*			new species : sphæriculata? Lam.		Unknown		*		
——				Duclosiana					
——				new species					
——				inflata					
——				leporina					
——			sanguinolenta		Senegal				
——				lyncoides					
Oliva	78	13	hiatula		Senegal				
——			flammulata		African Ocean, Madagascar				
——				clavula			*?		
——				Branderi					
——				mitreola					
Ancillaria	9	9		glandiformis			*		
——				canalifera					
——				buccinoidea					
——				inflata					
Terebellum	1	2		convolutum					
——				fusiforme					
Conus	181	49	Mediterraneus		Mediterr.	*			Morea
——				antediluvianus					
——				deperditus					
——				scabriusculus					
——				Brongniarti					
——				Brocchii			*		
——				alsiosus					
——				acutangulus					
——				mercati			*		
——				ponderosus					
——				distans					
——				pyrula			*		
——				new species					
Beloptera		1							
Sepiostera		3							
Sepia	4								
Nautilus	2	4		Deshayesii					
Nodosaria	28	21	lævigata		Mediterr.		*		
——			oblonga		ibid.				
——			sulcata		ibid.		*		
Frondicularia	2	5							
Lingulina	1	2	carinata		West Ind. Seas		*		
Rimulina	1								

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	......	..	..	......															
*	..	*	..	......	..	..	......															
..	*	..	..	Angers, Nantes	..	..	......															
..	..	..	..	......	*	*	Valognes .	3	6	3	..	4	8	5	6	..	..	3	4	1	2	
*	*	..	..	......	..	..	......															
..	*	*	..	......	..	..	......															
*	*	*	..	Angers . .	..	..	......															
*	*	..	..	......	..	..	......															
*	*	*	*	Angers . .	..	..	......															
*	*	*	..	......	..	..	......	..	1	..	..	4	4	3	2	..	1	1	6	3	3	1
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	Valognes, Belgium															
*	*	*	*	Volhynia . .	..	..	......															
*	*	*	*	Angers . .	*	*	Valognes .	..	1	..	..	2	2	4	2	..	2	..	5	4	3	
..	..	..	..	......	*	*	ibid. . .															
..	..	..	..	......	*	*	ibid. . .															
..	..	..	..	......	*	*	Pauliac, Valognes, Belgium	..	..	..	..	..	..	..	..	..	..	..	2	2	1	1
..	..	..	..	......	*	*	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	*	*	Valognes .															
..	..	..	..	......	*	*	......															
..	..	..	..	......	*	*	......															
*	..	*	*	Moravia . .	..	..	......															
*?	..	..	..	......	..	..	......															
*	..	*	*	......	..	..	......	1	10	..	2	14	7	9	3	1	7	2	7	4	2	
*	*	..	..	Angers, Volhynia, Moravia	..	..	......															
*	..	..	*	......	..	..	......															
..	*	*	..	......	..	..	......															
*	..	..	..	Angers . .	..	..	......															
..	..	..	*	......	..	..	......															
*	*	..	*	......	..	..	......															
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	1			
..	..	..	..	......	..	..	......	..	..	..	..	..	..	..	..	..	..	..	3	..	2	
*	..	..	..	......	*	*	......	..	..	..	..	..	2	..	..	..	..	..	3			
..	..	..	..	......	..	..	......															
*	..	..	..	......	..	..	......	..	18	..	..	3	1	..	..	..	..	..	2			
*	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	..	4	..	..	..	1									
..	..	..	..	......	..	..	......	..	1													

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	PLIOCENE PERIOD. Italy, Subap.	PLIOCENE PERIOD. English Crag.	PLIOCENE PERIOD. Various Localities.
Vaginulina	8								
Marginulina	9	5	raphanus	. . . . . .	Mediterr.	. .	*	. .	. . . . . .
Planularia	3	2	auris	. . . . . .	ibid.	. .	*	. .	. . . . . .
Pavonina	1								
Bigenerina	4								
Textularia	15	15	gibbosa	. . . . . .	Adriatic	. .	*	. .	. . . . . .
———	. .	. .	angularis	. . . . . .	ibid.	. .	. .	. .	. . . . . .
———	. .	. .	sagittula	. . . . . .	Mediterr.	. .	*	. .	. . . . . .
Vulvulina	3								
Dimorphina	1								
Polymorphina	23	11	. . . . . .	inequalis	. . . . . .	. .	*	. .	. . . . . .
———	. .	. .	pupa	. . . . . .	Mediterr.	. .	. .	. .	. . . . . .
———	. .	. .	communis	. . . . . .	Mediterr.	. .	*	. .	. . . . . .
———	. .	. .	caudata	. . . . . .	ibid.	. .	*	. .	. . . . . .
———	. .	. .	lævigata	. . . . . .	ibid.	. .	. .	. .	. . . . . .
———	. .	. .	gibba	. . . . . .	ibid.	. .	*	. .	. . . . . .
———	. .	. .	ovata	. . . . . .	ibid.	. .	. .	. .	. . . . . .
Virgulina	. .	1	. . . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Sphæroidina	1	1	bulloides	. . . . . .	Medit. Ind. Oc.	. .	*	. .	. . . . . .
Clavulina	2	3	communis	. . . . . .	Mediterr.	. .	*	. .	. . . . . .
Uvigerina	2	3	. . . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Bulimina	13	4	. . . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Valvulina	1	7	. . . . . .	pupa	. . . . . .	. .	. .	. .	. . . . . .
———	. .	. .	. . . . . .	globularis	. . . . . .	. .	. .	. .	. . . . . .
Rosalina	6	2	. . . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Rotalia	25	31	pileus	. . . . . .	Mediterr.	. .	. .	. .	. . . . . .
———	. .	. .	subrotunda	. . . . . .	ibid.	. .	*	. .	. . . . . .
———	. .	. .	armata	. . . . . .	Cayenne	. .	. .	. .	. . . . . .
———	. .	. .	. . . . . .	carinata	. . . . . .	. .	*	. .	. . . . . .
———	. .	. .	communis	. . . . .	Mediterr. Madagascar	. .	. .	. .	Etang de Tau
———	. .	. .	Italica	. . . . . .	Mediterr.	. .	*	. .	. . . . . .
Calcarina	5								
Globigerina	9	4	elongata	. . . . . .	Mediterr.	. .	*	. .	. . . . . .
Gyroidina	9	2	lævis	. . . . . .	ibid.	. .	*	. .	. . . . . .
Truncatulina	5	5	tuberculata	. . . . .	ibid. Ind. Oc. European Ocean	*	*	. .	. . . . . .
Planulina	4								
Planorbulina	4								
Operculina	2	2	. . . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Soldania	3	3	. . . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Cassidulina	1								
Anomalina	3	2	. . . . . .	. . . . . .	. . . . . .	. .	. .	. .	Etang de Tau

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
..	..	..	..	......	..	..	......	..	4	..	..	..	1									
..	..	..	..	......	..	..	......	..	2													
..	..	..	..	......	..	..	......															
*	..	..	..	......	..	..	......	..	6	..	..	..	3	..	..	..	..	1	1			
..	..	..	..	......	..	..	......															
..	..	..	..	Angers . .	..	..	......															
..	..	..	..	......	*	..	......															
*	..	..	..	......	..	..	......															
..	..	..	..	......	*?	..	......	..	8	..	..	5	6	1	..	..	..	3	10			
*	..	..	..	......	..	..	......															
*	..	..	..	Angers . .	*	..	......															
*	..	..	..	......	*?	..	......															
..	..	..	..	......	..	..	......	..	1													
..	..	..	..	......	..	..	......	..	1													
*	..	..	..	......	..	..	......	..	2	..	..	..	1	..	..	..	..	..	1			
..	..	..	..	......	..	..	......	..	2	..	..	..	1									
..	..	..	..	......	..	..	......	..	3	..	..	..	1									
..	..	..	..	......	*	..	Valognes .	..	..	..	..	..	..	..	..	..	..	..	4	..	5	
..	..	..	..	......	*	..	ibid. . .															
..	..	..	..	......	..	..	......	..	..	..	..	1	..	..	..	..	..	..	1			
*	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
*	..	..	..	Angers . .	..	..	......	..	5	..	..	9	3	..	..	..	..	1	12	..	2	
*	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......															
..	..	..	..	......	..	..	......	..	1	..	..	1	1	..	..	..	..	..	1			
*	..	..	..	......	..	..	......	..	1	..	..	1	..	..	..	..	..	..	1			
*	..	..	..	......	..	..	......	1	1	..	..	2	1	..	..	..	..	..	1			
..	..	..	..	......	..	..	......	..	..	..	..	1	1									
..	..	..	..	......	..	..	......	..	3													
..	..	..	..	......	..	..	......	..	..	..	..	1										

GENERA.	No. of Species: Living.	No. of Species: Fossil (tert.)	Species found both living and fossil (tertiary).	Species found fossil in more than one tertiary formation.	Habitations of living Species.	PLIOCENE PERIOD. Sicily.	Italy, Subapp.	English Crag.	Various Localities.
Vertebralina	1								
Polystomella	8	3	angularis . .	. . . . .	Senegal, Australian, Indian, Mediterr. and African Oceans.	. .	*	. .	. . . . . .
————	. .	. .	strigilata . .	. . . . . .	Coasts of Africa	. .	. .	. .	Etang de Tau
Dendritina .	2	1	. . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Peneroplis .	3	2	. . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Spirolina . .	. .	6	. . . . .	. . . . . .	. . . . . .	. .	. .	. .	. . . . . .
Robulina . .	17	10	cultrata . .	. . . . . .	Adriatic . . .	. .	. .	. .	. . . . . .
———— . .	. .	. .	calcar . . .	. . . . . .	ibid.	. .	*	. .	. . . . . .
———— . .	. .	. .	marginata .	. . . . . .	West Indian Seas	. .	. .	. .	. . . . . .
Cristellaria .	10	14	cassis . . .	. . . . . .	Mediterr. . .	. .	*	. .	. . . . . .
———— .	. .	. .	tuberculata .	. . . . . .	ibid. . . .	. .	*	. .	. . . . . .
———— .	. .	. .	Italica . . .	. . . . .	Mediterr. . . .	. .	*	. .	. . . . . .
Nonionina .	15	11	umbilicata .	. . . . .	ibid.	. .	*	. .	. . . . . .
————. .	. .	. .	communis .	. . . . .	ibid, Madagascar, West Indies	. .	*	. .	. . . . . .
Nummulites	1	13	. . . . .	. . . . .	. . . .	. .	. .	. .	. . . . . .
Biloculina .	4	8	bulloides . .	. . . . . .	Mediterr. . . .	. .	*	. .	. . . . . .
————. .	. .	. .	. . . . .	ringens . . .	. . . .	. .	. .	. .	. . . . . .
————. .	. .	. .	longirostris .	. . . . .	Mediterr. . . .	. .	*	. .	. . . . . .
————. .	. .	. .	depressa . .	. . . . .	ibid.	. .	*	. .	. . . . . .
————. .	. .	. .	lævis . . .	. . . . .	ibid.	*	. .	. .	. . . . . .
Spiroloculina	6	9	depressa . .	. . . . .	ibid.	. .	*	. .	. . . . . .
Triloculina .	16	12	. . . . .	trigonula . .	. . . .	. .	. .	. .	. . . . . .
————. .	. .	. .	gibba . . .	. . . . . .	Mediterr. . . .	. .	*	. .	. . . . . .
————. .	. .	. .	inflata . . .	. . . . . .	ibid.	. .	*	. .	. . . . . .
————. .	. .	. .	oblonga . .	. . . . .	ibid., Indian & European Oceans	. .	*	. .	. . . . . .
————. .	. .	. .	Brongniarti	. . . . . .	West Indies. .	. .	*	. .	. . . . . .
Articulina .	. .	1	. . . . .	. . . . . .	. . . .	. .	. .	. .	. . . . . .
Quinqueloculina	30	23	undulata . .	. . . . . .	Mediterr. . . .	. .	*	. .	. . . . . .
————	. .	. .	triangularis .	. . . . .	ibid. St. Helena	. .	*	. .	. . . . . .
————	. .	. .	bicarinata .	. . . . . .	Mediterr. . . .	. .	*	. .	. . . . . .
————	. .	. .	seminulum .	. . . . .	ibid.	. .	*	. .	. . . . . .
Adelosina .	2	2	. . . . .	. . . . .	. . . .	. .	. .	. .	. . . . . .
Amphistegina	6	1	. . . . .	. . . . . .	. . . .	. .	. .	. .	. . . . . .
Heterostegina	2								
Orbiculina .	1								
Alveolina. .	1	5	. . . . .	. . . . . .	. . . .	. .	. .	. .	. . . . . .
Fabularia. .	. .	1	. . . . .	. . . . . .	. . . .	. .	. .	. .	. . . . . .

MIOCENE PERIOD.					EOCENE PERIOD.			No. of Species in each Genus in the following Localities.														
Bordeaux, Dax.	Touraine.	Turin.	Vienna.	Various Localities.	Paris.	London.	Various Localities.	Sicily.	Italy, Subap.	English Crag.	Baden.	Bordeaux.	Dax.	Touraine.	Turin.	Ronca.	Vienna.	Angers.	Paris.	London.	Valognes.	Belgium.
	*			Angers, Nantes					2					1				1				
												1										
													1						1			
																			6			
			*																			
									8			1					1					
*																						
									14													
*									5			4	3						1			
*																						
												3	2						5		2	2
*																						
					*		Valognes.															
								1	2			4							3			
									4			1	2						3			
					*		Valognes.															
*									4				4						5		2	
*					*																	
																			1			
*									7			2	1						14			
									2													
												1										
													1						3			
																			1		1	

SUPPLEMENTARY TABLE,

Containing Localities for which there was not sufficient space in the preceding tables.

GENERA.	Scotland.	Perpignan.	Morea.	Osseous brecias.	Teneriffe.	Quercy.	Nice.	St. Helena.	Lauzerte.	Agen.	Val d'Arno.	Etang de Tau.	India.	Mayence.	Egypt.	Germany.	Maryland.	Doué.	Montpellier.	Auvergne.	Alsace.	Bavaria, Hungary, &c.	St. Esprit.	Klein Spaunen.	Localities unknown.
Cyclas	1																								
Cyrena													1	2											
Tridacna															1	1									
Perna																	1								
Pecten		6	4															3	3						
Hinnites																			2						
Helix				6	1	1								1						2	2				7
Pupa							1		1																
Bulimus								1																	
Achatina																					1				
Planorbis				2		2														3		1			
Limnea									4	2										3					
Paludina											5			2								5			
Ampullaria																							2		
Cerithium														1					4					4	
Textularia												4													
Anomalina												1													

GENERAL RESULTS

DEDUCED FROM

A COMPARISON OF THE SPECIES EXAMINED IN COMPILING THE FOREGOING TABLES.

PLIOCENE PERIOD.

Italy, Sicily, the Morea, Perpignan, and the English Crag. The fossils of Perpignan and the Morea are, with the exception of three or four species, the same as those of Italy.

	No. of species.						
In Italy .	569,	of which	238	are still living, and	331	extinct (or *unknown*)
Sicily .	226	,,	216	,,	10	,,
The Crag	111	,,	45	,,	66	,,
	906					

No. of species common to	Italy and Sicily .	103
	Italy and the Crag*	4
	Sicily and the Crag	4
	Italy, Sicily, and the Crag	18
		129

No. of species proper to	Sicily .	65
	to the Crag .	23

By subtracting from the total number of species enumerated as belonging to the above localities . . .	906
those species which are common to different localities .	129
We find the real number of the species of this epoch to be .	777

The number of living analogues is 350, which is in the proportion of 49 in 100.

MIOCENE PERIOD.

Bordeaux, Dax, Touraine, Turin, Baden, Vienna, Moravia, Hungary, Cracovia, Volhynia, Podolia, Transylvania, Angers, and Ronca†.

The species of Moravia, Hungary, Cracovia, Volhynia, Podolia, and Transylvania, are the same, with a very few exceptions, as those of Vienna and Baden.

* The statement that there are only 4 species common to Italy and the Crag, may seem inconsistent with the fact that 18 are common to those places and to Sicily; but the reader will understand that there are only 4 species which are common to Italy and the Crag, and which are not also common to some *other Pliocene locality*. The same remark is applicable to similar statements in the sequel.

† Ronca may very probably belong to the Eocene epoch; but in this, as in respect to a few other localities mentioned in the tables, the number of analogues is too small to lead to certain conclusions.

	No. of species.				
Bordeaux and Dax*	594, of which	136	are still living, and	458	extinct.
Touraine . .	298	,, 68	,,	230	,,
Turin . .	97	,, 17	,,	80	,,
Vienna . .	124	,, 35	,,	89	,,
Baden . .	99	,, 26	,,	73	,,
Angers . .	166	,, 25	,,	141	,,
Ronca . .	40	,, 3	,,	37	,,
	1418				

	No of species.
Common to Bordeaux, Dax, Touraine	62
ib. ib. Turin	18
ib. ib. Vienna	23
ib. ib. Baden	13
ib. ib. Angers	8
ib. ib. Ronca	0
ib. ib. Touraine and Turin . . .	12
ib. ib. Touraine and Vienna . .	17
ib. ib. Touraine and Baden . . .	4
ib. ib. Touraine and Angers . .	14
ib. ib. Touraine and Ronca . . .	0
ib. ib. Touraine, Turin and Vienna .	8
ib. ib. Touraine, Turin and Angers .	2
ib. ib. Touraine, Vienna and Angers .	7
ib. ib. Turin and Vienna . . .	6
ib. ib. Turin and Ronca . . .	1
ib. ib. Baden and Angers . . .	1
Touraine and Angers	10
Touraine and Turin	3
Touraine and Vienna	15
Touraine and Baden	2
Turin and Ronca	2
Vienna and Angers	2
Angers and Ronca	1
Touraine, Vienna and Baden	2
Touraine, Vienna, Angers and Baden . .	1
Bordeaux, Dax, Touraine, Turin, Vienna and Angers	3
ib. ib. ib. Turin, Vienna and Baden	3
ib. ib. ib. Vienna and Baden .	14
ib. ib. ib. Vienna, Angers and Baden	2
Carried over . . .	256

* There are at Bordeaux . . 446 species
and at Dax . . . 473

making a total of . . 919

but from the great number of species common to the two localities there are, in reality, only 594 species, as above mentioned.

	No. of Species
Brought over	256
Common to Bordeaux, Dax, Touraine, Turin, Vienna, Angers & Baden	1
ib. ib. ib. Angers and Baden	2
ib. ib. Vienna and Baden	4
	263
By adding to the above 134 species which are common to the Miocene, and the two other epochs	134
the total number of analogues will be found to be	397
By subtracting from the total number of species of the above localities	1418
those species which are common to different localities	397
We find the real number of species of this epoch to be	1021

The number of living analogues is 176, which is in the proportion of rather less than 18 in 100; the number of fossil analogues, after subtracting those which pass from the Miocene into both the Pliocene and Eocene epochs, is 168, which is very nearly in the same proportion.

The species which pass from the Miocene into the Pliocene period are in number 196, of which 114 are living, and 82 fossil, which is very nearly in the proportion of 20 in 100 of the total number of species of the latter epoch. Thus it is remarkable that there are 18 in 100 living analogues, 18 in 100 of analogous fossil species, and that 20 in 100 of these species pass from the Miocene to the Pliocene epoch.

The 114 living species, and the 82 fossil ones, which are common to the Miocene and Pliocene periods, are distributed, in the last-mentioned epoch, in the following manner:—

Living.		Fossil.	
Crag	4	Crag	4
Italy	48	Sicily	1
Sicily	5	Italy	71
Sicily and Italy	46	Sicily and Italy	5
Sicily, Italy, and the Crag	11	Sicily and the Crag	1
	114		82

The preceding distribution of species will show that Italy is represented in the Miocene period by 181 species, Sicily by 69, and the Crag by 20.

EOCENE PERIOD.

Paris, London, Valognes, Belgium, Castelgomberto, and Pauliac.

A small number of species only have been examined from Belgium, Pauliac, and Castelgomberto, but which agreed, with few exceptions, with species of the Paris basin. So also in regard to Valognes.

Number of species, Paris	.	1122	of which 38 are still living, and 1084 extinct (or unknown).
London	.	239	of which 12 are still living, and 227 extinct (or unknown).
Valognes	.	332	
Belgium	.	49	
		1742	
By subtracting from these localities the number of analogous species	.	504	
The real number of species of this epoch is	.	1238	

The number of fossils of this period identified with living species is 42, which is to 1238 in the proportion of $3\frac{1}{4}$ in 100. The number of fossil species which pass from the Eocene into the two other periods is 46, that is to say, in nearly the same proportion as the living analogues. Among the fossil species, four only are common to the three epochs, which are the following:—

1 Dentalium coarctatum.
2 Tornatella inflata.
3 Bulimus terebellatus.
4 Corbula complanata.

The 42 other fossil species, which go no farther than the Miocene epoch, are distributed in the following manner:—

Bordeaux and Dax	17
Turin	3
Angers	2
Ronca	7
Bordeaux, Dax and Touraine	4
ib. ib. and Turin	1
ib. ib. Touraine and Angers	2
ib. ib. Turin, Vienna and Baden	1
ib. ib. Touraine, Turin, Vienna and Angers	1
ib. ib. Touraine, Vienna, Angers and Baden	1
Turin and Ronca	2
Angers and Ronca	1
	42

Of the 42 living species, the following 13 are common to the three epochs,—

1 Dentalium entalis,
2 ——— strangulatum,
3 Fissurella græca,
4 Bulla lignaria,
5 Rissoa cochlearella,
6 Murex fistulosus,
7 Murex tubifer,
8 Polymorphina gibba,
9 Triloculina oblonga,
10 Lucina divaricata,
11 ——— gibbosula,
12 Isocardia cor,
13 Nucula margaritacea.

Of the other species, 7 go no farther than the Miocene epoch, and are distributed in the following manner,—

Bordeaux and Dax		3
ib.	ib. and Baden	1
ib.	ib. and Touraine	1
ib.	ib. and Angers	1
ib.	ib. Touraine and Angers	1
		7

Total number of species in the three periods,—

In the Pliocene	777
In the Miocene	1021
In the Eocene	1238
	3036

From the above lists it will appear that there are 17 species which are common to the three epochs, and which may therefore be said to characterise the entire tertiary formations of Europe. Thirteen of them are species still living, while four are only known as fossil. There is not a single species common to the Pliocene and Eocene epochs which is not also found in the Miocene.

Geographical Distribution of the living Species which have their fossil Analogues.

Pliocene Epoch, 350 *species.*

In the Mediterranean	242	Fossil in Sicily and Italy.
In the Indian Ocean	25	
At Senegal	5	
Common to the Mediterranean and Senegal	14	
——— and the African Ocean	8	
——— Indian Ocean and to Senegal	7	
——— and to America	5	
In the Northern European Ocean	43	Fossil in the Crag.
—— Pacific Ocean	1	
	350	

Miocene Epoch, 176 *species,* (100 *species common to the preceding epoch.*)

	Species.
At Senegal, of which 13 are common to the Indian Ocean, and 12 to the Mediterranean	79
In the Mediterranean and Southern European Ocean, of which 10 are common to the Indian Ocean, and 12 to Senegal	86
In the Indian Ocean, 10 of which are common to the Southern European Ocean	29
Carried over	194

	Species.
Brought over	194
In the Equatorial Seas of America, 2 of which are common to the Indian Ocean	7
In the Pacific Ocean	2
	203
Number common to different localities	27
	176

Eocene Epoch, 42 *species, of which* 26 *are common to the two preceding epochs.*

In the Mediterranean, 5 of which are common to India and New Holland	19
In the Indian Ccean	7
In New Holland	3
In Senegal	3
	32
Of the fluviatile and terrestrial species, 5 are still living in Europe, 1 in the Philippine Islands, and 4 in Asia, Spain and Greece	10
	42

APPENDIX II.

I.—FOSSIL SHELLS COLLECTED BY THE AUTHOR FROM VARIOUS LOCALITIES OF THE NEWER PLIOCENE FORMATION IN SICILY; NAMED BY M. DESHAYES.

N. B. Those which are marked with an asterisk in this and the following lists are unknown as recent.

FOSSIL SHELLS FROM THE FLANKS OF ETNA, IMMEDIATELY ABOVE THE BAY OF TREZZA.

In clay and volcanic tuff. (See p. 79.)

Mactra triangula, *Broc.*
Corbula nucleus.
Astarte, unnamed.
,, ditto.
Venus Brongniarti, *Payraudeau.*
,, radiata.
,, species doubtful.
Cytherea exoleta.
,, lincta.
Cardium edule.
,, sulcatum.
Arca antiquata, *Lamk.*
,, barbata, *Lamk.*
Pectunculus glycimeris.
,, pilosus.
Nucula, new species.
,, margaritacea.
Chama unicornis.
Pecten ornatus.
,, an, new species?
,, Bruei, *Payr.*
,, opercularis.
,, unicolor.
,, Jacobæus.
Ostrea edulis.
Anomia ephippium.
Dentalium entalis.
,, * new species.
,, strangulatum, *Desh.*
,, novem costatum.
Pileopsis Ungarica.
Calyptræa Chinensis.
Natica millepunctata.
Natica Dillwynii, *Payr.*
,, Guillemini, *Payr.*
,, glaucina.
Trochus magus.
,, conulus.
,, Adansoni, *Payr.*
Turbo rugosus.
Monodonta Viellotii, *Payr.*
Turritella terebra, *Broc.*
Cerithium sulcatum.
Pleurotoma, new species.
Cancellaria cancellata.
Fusus, new species.
,, new species.
,, craticulatus, *Blainv.*
,, strigosus.
,, lignarius.
Murex trunculus.
,, Brandaris.
,, erinaceus.
Triton an pileare?
Rostellaria pes pelicani.
Cassidaria echinophora.
Buccinum musivum, *Broc.*
,, mutabile.
,, maculosum.
,, unnamed.
,, Calmelii.
* ,, semistriatum.
Colombella rustica.
Mitra lutescens.
Conus Mediterraneus

VILLASMONDE. (See p. 65.)

Mactra lactæa.
Corbula nucleus.
Pecten opercularis.
Dentalium novem costatum.
Natica glaucina.
,, canrena.
Rostellaria pes pelicani.

MILITELLO. (V. di Noto.) (See p. 65.)

Cytherea chione?
Cardium edule.
Arca antiquata.
Pecten Jacobæus.
,, varius.
Pecten opercularis.
Ostrea edulis.
* Dentalium, new species.
Buccinum prismaticum?
An Turbo rugosus???

GIRGENTI.—(*In limestone and clay.*—See p. 65.)

Corbula nucleus.
Mactra triangula? *Broc.*
Pectunculus pilosus.
Modiola, species doubtful.
Pecten Jacobæus.
Pecten opercularis.
Dentalium entalis.
Natica millepunctata.
* Turritella tornata.
* Buccinum semistriatum.

SYRACUSE. (See p. 67.)

Thracia pubescens.
* Tellina?
Cardium sulcatum.
,, edule.
,, echinatum.
Isocardia cor.
Arca antiquata.
Pectunculus pilosus.
,, glycimeris.
Pecten, an nodosus?
,, Jacobæus.
,, Audouini, *Payr.*
,, opercularis.
Pecten coarctatus, *Broc.*
,, varius.
Ostrea edulis.
* Dentalium, new species.
,, strangulatum, *Desh.*
,, sexangulare, *Broc.*
Haliotis tuberculata.
Trochus conulus.
Turritella terebra.
Murex trunculus?
* Buccinum semistriatum.
Cypræa rufa.
Conus Mediterraneus??

CALTANISETTA.—(*In clay and yellow sand.*—See p. 67.)

Lucina lactea?
Venus multilamella.
Cardium echinatum.
,, edule.
Arca antiquata.
Pecten Jacobæus.
Ostrea edulis.
* Dentalium, new species.
,, fossile.
,, sexangulare.
Natica Guillemini, *Payr.*
,, millepunctata.
Turritella subangulata, *Broc.*
* ,, tornata, *Broc.*
,, terebra.
Cerithium vulgatum.
Fusus lignarius.
Rostellaria pes pelicani.
* Buccinum semistriatum.
Mitra lutescens.

CALTAGIRONE. (See p. 67.)

Mactra triangula, *Broc.*
Amphidesma, new species.
Corbula nucleus.
Psammobia angulata (Tellina, *Lin.*)
Cytherea lincta.
Venus multilamella.
Cardita sulcata, *Brug.*
,, squamosa.
Cardium echinatum.
Arca antiquata.
* Nucula Italica, *Def.*
Pecten opercularis.
,, Bruei, *Payr.*
Dentalium, new species.
,, entalis.
,, novem costatum.
Fissurella costaria, *Desh.*
Calyptræa chinensis.
Bulla lignaria.
Natica canrena.
Natica Dilwynii, *Payr.*
,, Valenciennesii, *Payr.*
,, Guillemini, *Payr.*
Scalaria tenuicostata, *Mich.*
Turritella terebra.
Cerithium Latreillei, *Payr.*
* Pleurotoma, new species.
,, vulpecula, *Broc.*
,, craticulata, *Broc.*
Fusus craticulatus, *Blain.*
,, lignarius.
,, rostratus.
Murex Brandaris.
Rostellaria pes pelicani.
* Buccinum semistriatum.
,, mutabile.
,, prismaticum, *Broc.*
* ,, turbinellus, *Broc.*
Mitra lutescens.
Cypræa oryza, *Duclos.*

CASTROGIOVANNI. (See p. 67.)

Lucina lactea.
* Nucula Italica, *Def.*
Pecten Jacobæus.
Pecten opercularis.
Natica Guillemini, *Payr.*

VIZZINI.

Murex Brandaris.

PIAZZA.

Ostrea edulis.

VAL DI NOTO.

Pectunculus glycimeris.
Pecten opercularis.

PALERMO.—(*In limestone and clay.*—See p. 65.)

* Clavagella bacillaris, *Desh.*
Solen coarctatus, *Broc.*
Panopea Aldrovandi.
Thracia corbuloides, *Desh.*
,, pubescens, *Desh.*
Lutraria solenoides.
Corbula nucleus.
Tellina Donacina.
,, new species.
Lucina radula.
,, new species, a lupinus? *Broc.*
,, lactea.
Astarte, new species, an incrassata?
,, new species.

PALERMO—continued.

Cytherea rugosa, *Broc.*
,, exoleta.
,, Chione.
Venus radiata, *Broc.*
,, species doubtful.
Cardita squamosa.
Cyprina Islandicoides.
Cardium sulcatum.
,, edule.
,, echinatum.
,, Deshayesii, *Payr.*
Isocardia cor.
Arca antiquata.
Pectunculus pilosus.
Nucula, new species.
,, margaritacea.
Chama gryphoides?
,, unicornis.
Pecten ornatus.
,, coarctatus, *Broc.*
,, an, new species.
,, opercularis.
,, new species.
,, Jacobæus.
,, varius ? ?
,, pleuronectes.
Ostrea cornucopiæ?
,, edulis.
,, Virginica.
,, hippopus.
Terebratula truncata.
* ,, ampulla.
* Dentalium, new species.
* ,, fossile, *Lin. Var.*
,, strangulatum, *Desh.*
Patella bonnardii, *Payr.*
Emarginula curvirostris, *Desh.*
Fissurella, species doubtful.
,, Græca.
Pileopsis Ungarica.
Bulla lignaria.
Auricula buccinea.
Natica millepunctata.
,, Guillemini, *Payr.*
Natica Canrena.
,, Valenciennesii, *Payr.*
Scalaria communis.
,, pseudo scalaris.
Solarium stramineum?
Trochus magus.
,, agglutinans.
,, cingulatus, *Broc.*
,, Adansoni, *Payr.*
,, conulus.
,, cinereus.
Turbo rugosus.
Turritella terebra.
Cerithium tricinctum.
* ,, margaritaceum.
* ,, new species.
Pleurotoma Cordieri.
,, Caumarmondi, *Mich.*
,, new species.
Fasciolaria tarentina.
Fusus sinistrorsus, *Desh.*
,, strigosus.
,, rostratus.
* ,, clavatus.
,, craticulatus.
* ,, new species.
,, lignarius.
Ranella gigantea.
* ,, lævigata.
Murex Brandaris.
,, trunculus.
Triton unifilosum, *Bon.*
Rostellaria pes pelicani.
Cassidaria echinophora.
Cassis saburon.
Dolium pomum.
Buccinum prismaticum, *Broc.*
,, new species.
,, new species.
* ,, semistriatum.
,, new species.
,, mutabile.
Conus Mediterraneus.

2.—FOSSIL SHELLS COLLECTED BY THE AUTHOR IN ISCHIA, AND NAMED BY M. DESHAYES. (See p. 126.)

Solen coarctatus, *Broc.*
Lucina lupinus, *Broc.*
Venus radiata, *Broc.*
,, verrucosa.
Cardium sulcatum.
,, edule.
Pectunculus violacescens.
Arca, new species, An arca quoyi? *Payr.*
Nucula margaritacea.
Pecten varius.
,, Jacobæus.
,, Dumasii, *Payr.*
,, opercularis.
Dentalium novem costatum.
Melania Cambessedesii, *Payr.*
Natica Guillemini, *Payr.*
,, Valenciennesii? *Payr.*
Trochus magus.
,, conuloides.
,, new species.
Turritella terebra.
Cerithium Latreillei, *Payr.*
,, new species.
,, vulgatum.
,, doliolum, *Broc.*
Rostellaria pes pelicani.
Buccinum prismaticum, *Broc.*
Cypræa lurida.

The four following shells have since been sent to me from Ischia. They are all of recent species:—

Pectunculus pilosus.
Natica glaucina?
Trochus crenulatus.
Turritella duplicata.

FOSSIL SHELLS FROM THE WESTERN BORDERS OF THE RED SEA, COLLECTED BY MR. JAMES BURTON, COMMUNICATED BY G. B. GREENOUGH, ESQ., P.G.S.

Lutraria solenoides?
,, plicatella??
Mactra stultorum?
Corbula.
Psammobia.
Tellina lingua felis.
,, rugosa.
,, virgata.
,, rostrata.
Lucina globosa.
Cyprina.
Cytherea tigerina.
,, picta.
,, castrensis.
,, erycina.
,, scripta?
Venus geographica.
,, reticulata.
,, ovata??
,, paphia.
Cardium rugosum.
,, Æolicum?
,, retusum.
Cardita turgida.
,, calyculata.
Cypricardia.
Chama lazarus.
Tridacna squamosa.
Arca scapha.
,, antiquata.
,, Noæ.
Pectunculus pectiniformis.
Pecten maximus.
,, pes felis.
Spondylus gaderopus.
Parmophorus elegans.
Fissurella Græca.
Bulla ampulla.
,, solida.
Helix desertum.
Nerita.
Natica melanostoma.
,, mamillaris.
,, mamilla.
,, Græca.
,, alba.
Haliotis tuberculata?
,, striata?
Tornatella.
Pyramidella.

RED SEA SHELLS—continued.

Solarium perspectivum.
Trochus maculatus.
,, virgatus.
,, Mauritianus.
Monodonta tectum.
,, Pharaonis.
,, Ægyptica.
Turbo chrysostomus.
,, petholatus.
Turritella
Cerithium nodulosum.
,, sulcatum.
,, virgatus.
Pleurotoma virgo.
Turbinella lineolata.
Cancellaria contabulata.
Fasciolaria trapezium.
Pyrula abbreviata.
,, rapa.
,, citrina.
,, reticulata.
,, francolinus.
Ranella granifera.
,, crumena.
Murex crassispina.
,, scorpio.
Triton variegatum.
,, lampas.
,, pileare.
,, maculosum.
Strombus gigas (young).
,, bituberculatus.
,, lineolatus.
,, gibberulus.
,, terebellatus.
Cassis vibex.
,, saburon.
,, erinaceus.
Ricinula arachnoides.
Dolium perdix.
Dolium pomum.
Buccinum coronatum.
,, arcularia.
,, senticosum.
Terebra crenulata.
,, subulata.
,, myosurus.
,, maculata.
,, duplicata.
Colombella turturina ?
Mitra striatula.
,, coronata ?
Cypræa mappa.
,, Arabica.
,, talpa.
,, caurica.
,, vitellus.
,, erosa.
,, carneola.
,, turdus ?
,, lurida ?
,, flaveola ?
,, nucleus.
,, stercus muscarum ?
,, caput serpentis ?
Ancillaria.
Oliva erythrostoma.
Conus arenatus.
,, generalis.
,, literatus ?
,, betulinus.
,, striatus.
,, episcopus.
,, tessellatus.
,, textile.
,, nussatella.
,, clavus.
,, terebra ? ?
,, capitaneus.
Terebellum subulatum.

The above shells were named by Mr. GRAY, F.R.S., and Mr. Frembley.

FOSSIL SHELLS COLLECTED BY THE AUTHOR FROM THE LOESS OF THE VALLEY OF THE RHINE.

(See p. 151.)

Helix obvoluta, *Drap.*
,, ericetorum, *ib.*
,, carthusianella, *ib.*
,, plebeium, *ib.*
,, pomatia.
,, nemoralis, *ib.*
,, fruticum, *Drap.*
,, arbustorum.
Helix striata, *Drap.*
Succinea elongata.
Cyclas palustris, *Drap.*
,, lacustris, *ib.*
Valvata piscinalis.
Limnea ovata, *Drap.*
Paludina impura.

SIENNA. (See pp. 160 and 163.)

Serpula arenaria.
,, ditto, var.
* ,, new species.
* ,, glomerata.
Mactra triangula.
Tellina complanata.
* Cytheræa rugosa, *Broc.*
Cardita intermedia.
* ,, new species.
Cardium edule.
Arca antiquata.
Pectunculus pilosus.
,, nummarius.
* ,, auritus.
Nucula margaritacea.
Pecten Jacobæus.
,, opercularis.
* ,, striatus ?
* ,, laticostatus.
Ostrea edulis, *Lin.*
,, edulis ? junior.
* ,, (nobis incognita).
Dentalium sexangulare.
* ,, fossile.
Auricula buccinea, *Desh.*
Melanopsis buccinoides.
Natica glaucina.
,, punctata.
,, Marochiensis.
Trochus fermonii, *Payr.*
* ,, new species, with its colour.
Turbo rugosus.
Turritella terebra.
* ,, imbricataria, *Broc.*
,, subangulata.
* ,, tornata.
* ,, varicosa.
Cerithium vulgatum.
,, doliolum.
* ,, tricinctum.
* ,, new species.
* ,, new species.
* Pleurotoma cataphracta.
* ,, interrupta, *Broc.*
* ,, oblonga, *Broc.*
* Pleurotoma rotata, *Broc.*
* ,, reticulata, *Broc.*
* ,, textilis, *Broc.*
* ,, turricula, *Broc.*
* ,, dimidiata, *Broc.* (dentata, *Lamk.*)
* ,, dimidiata, var.
Cancellaria cancellata.
* ,, varicosa.
* ,, Lyrata.
Fusus lignarius
* ,, mitræformis.
,, subulatus.
* ,, longiroster.
* ,, thiara, *Broc.*
* Ranella bimarginata.
Murex cornutus, var.
,, tubifer.
* ,, horridus.
* ,, spirispina.
,, pomum.
* ,, bracteatus, *Broc.*
* ,, new species.
Triton unifilosus, *Bonelli.*
* ,, reticularis, *Broc.*
* ,, new species.
Rostellaria pes pelicani.
* Strombus Bonelli, *Brong.*
Cassis saburon.
Buccinum clathratum ? *Broc.*
* ,, serratum, *Broc.*
* ,, costulatum.
* ,, gibbosulum.
* Terebra plicaria.
* ,, duplicata.
* Mitra pyramidella, *Broc.*
* ,, scrobiculata.
Marginella cypræola.
* Conus antediluvianus, *Broc.*
* ,, ponderosus.
* ,, mercator.
* ,, pyrula, *Broc.*
* ,, betulinoides.
* ,, virginalis.

SECONDARY FOSSIL SHELLS.

FOSSIL SHELLS COMMON TO THE MAESTRICHT BEDS AND THE WHITE CHALK; COMMUNICATED BY M. DESHAYES. (See p. 325.)

Catillus (Inoceramus) Cuvieri? (specimens imperfect.)
Plagiostoma spinosa.
„ Hoperi.
Pecten fragilissimus.
Ostrea vesicularis.
„ carinata.
Crania Parisiensis.
Terebratula octoplicata.
„ carnea.
„ pumilus (magus, *Sow.*)
„ Defrancii.
Belemnites mucronatus.

FOSSIL SHELLS COMMON TO THE MAESTRICHT BEDS AND THE UPPER GREEN-SAND; COMMUNICATED BY M. DESHAYES. (See p. 325.)

Plagiostoma spinosa.
Ostrea vesicularis.
„ carinata.
Belemnites mucronatus.
Baculites Faujasii.

GLOSSARY

Of Geological and other Scientific Terms used in this Work.

Several of the Author's friends, who had read the first and second volumes of the Principles of Geology, having met with difficulties from their previous unacquaintance with the technical terms used in Geology and Natural History, suggested to him that a Glossary of those words would render his work much more accessible to general readers. The Author willingly complied with this suggestion, but finding that his own familiarity with the subject made him not a very competent judge of the terms that required explanation, he applied to the friends above alluded to for their assistance, and from lists of words supplied by them, the following Glossary has been constructed. It will be obvious to men of science, that in order to attain the object in view, it was necessary to employ illustrations and language as familiar as possible to the general reader.

ACEPHALOUS. The Acephala are that division of molluscous animals which, like the oyster and scallop, are without heads. The class Acephala of Cuvier comprehends many genera of bivalve shells, and a few genera of mollusca which are devoid of shells. *Etym.*, *a*, *a*, without, and κεφαλη, *cephale*, the head.

ALGÆ. An order or division of the cryptogamic class of plants. The whole of the sea-weeds are comprehended under this division, and the application of the term in this work is to marine plants. *Etym.*, *Alga*, sea-weed.

ALUM-STONE, ALUMEN, ALUMINOUS. Alum is the base of pure clay, and strata of clay are often met with containing much iron-pyrites. When the latter substance decomposes, sulphuric acid is produced, which unites with the aluminous earth of the clay to form sulphate of alumine, or common alum. Where manufactories are established for obtaining the alum, the indurated beds of clay employed are called Alum-stone.

ALLUVIAL. The adjective of alluvium, which see.

ALLUVION. Synonymous with alluvium, which see.

ALLUVIUM. Earth, sand, gravel, stones, and other transported matter which has been washed away and thrown down by rivers, floods, or other causes, upon land not *permanently* submerged beneath the waters of lakes or seas. *Etym.*, *Alluo*, to wash upon. For a further explanation of the term, as used in this work, see vol. ii. chap. xiv., and vol. iii. p. 145.

Ammonite. An extinct and very numerous genus of the order of molluscous animals, called Cephalopoda, allied to the modern genus Nautilus, which inhabited a chambered shell, curved like a coiled snake. Species of it are found in all geological periods of the secondary strata; but they have not yet been seen in the tertiary beds. They are named from their resemblance to the horns on the statues of Jupiter Ammon.

Amorphous. Bodies devoid of regular form. *Etym.*, α, *a*, without, and μορφη, *morphe*, form.

Amygdaloid. One of the forms of the Trap-rocks, in which agates and simple minerals appear to be scattered like almonds in a cake. *Etym.*, αμυγδαλα, *amygdala*, an almond.

Analcime. A simple mineral of the Zeolite family, of frequent occurrence in the trap-rocks.

Analogue. A body that resembles or corresponds with another body. A recent shell of the same species as a fossil-shell, is the analogue of the latter.

Anoplothere, Anoplotherium. A fossil extinct quadruped belonging to the order Pachydermata, resembling a pig. It has received its name because the animal must have been singularly wanting in means of defence, from the form of its teeth and the absence of claws, hoofs, and horns. *Etym.*, ανοπλος, *anoplos*, unarmed, and θηριον, *therion*, a wild beast.

Antagonist Powers. Two powers in nature, the action of the one counteracting that of the other, by which a kind of equilibrium or balance is maintained, and the destructive effect prevented that would be produced by one operating without a check.

Antennæ. The articulated horns with which the heads of insects are invariably furnished.

Anthracite. A shining substance like black-lead; a species of mineral charcoal. *Etym.*, ανθραξ, *anthrax*, coal.

Anthracotherium. A name given to an extinct quadruped, supposed to belong to the Pachydermata, the bones of which were found in lignite and coal of the tertiary strata. *Etym.*, ανθραξ, *anthrax*, coal, and θηριον, *therion*, wild beast.

Anthropomorphous. Having a form resembling the human. *Etym.*, ανθρωπος, *anthropos*, a man, and μορφη, *morphe*, form.

Anticlinal Axis. If a range of hills, or a valley, be composed of strata, which on the two sides dip in opposite directions, the imaginary line that lies between them, towards which the strata on each side rise, is called the anticlinal axis. In a row of houses with steep roofs facing the south, the slates represent inclined strata dipping north and south, and the ridge is an east

and west anticlinal axis. For a farther explanation, with a diagram, see vol. iii. p. 293.

ANTISEPTIC. Substances which prevent corruption in animal and vegetable matter, as common salt does, are said to be antiseptic. *Etym.*, *αντι*, *against*, and *σηπω*, *sepo*, to putrefy.

ARENACEOUS. Sandy. *Etym.*, *Arena*, sand.

ARGILLACEOUS. Clayey, composed of clay. *Etym.*, *Argilla*, clay.

ARRAGONITE. A simple mineral, a variety of carbonate of lime, so called from having been first found in Arragon, in Spain.

AUGITE. A simple mineral of a dark green, or black colour, which forms a constituent part of many varieties of volcanic rocks.

AVALANCHES. Masses of snow which, being detached from great heights in the Alps, acquire enormous bulk by fresh accumulations as they descend; and when they fall into the valleys below often cause great destruction. They are also called *lavanges*, and *lavanches*, in the dialects of Switzerland.

BASALT. One of the most common varieties of the Trap-rocks. It is a dark green or black stone, composed of augite and felspar, very compact in texture, and of considerable hardness, often found in regular pillars of three or more sides, called basaltic columns. Very remarkable examples of this kind of rock are seen at the Giant's Causeway, in Ireland, and at Fingal's Cave, in the island of Staffa, one of the Hebrides. The term is used by Pliny, and is said to come from *basal*, an Æthiopian word signifying iron, not an improbable derivation, inasmuch as the rock often contains much iron, and as many of the figures of the Egyptian temples are formed of basalt.

'BASIN' of Paris, 'BASIN' of London. Deposits lying in a great hollow or trough surrounded by low hills or high land, sometimes used in geology almost synonymously with 'formation.'

BELEMNITE. An extinct genus of the order of molluscous animals called Cephalopoda, that inhabited a long, straight, and chambered conical shell. *Etym.*, *βελεμνον*, *belemnon*, a dart.

BITUMEN. Mineral pitch, of which the tar-like substance which is often seen to ooze out of the Newcastle coal when on the fire, and which makes it cake, is a good example. *Etym.*, *Bitumen*, pitch.

BITUMINOUS SHALE. An argillaceous shale, much impregnated with bitumen, which is very common in the coal measures.

BLENDE. A metallic ore, a compound of the metal zinc with sulphur. It is often found in brown shining crystals, hence its name among the German miners, from the word *blenden*, to dazzle.

BLUFFS. High banks presenting a precipitous front to the sea or a river. A term used in the United States of North America.

BOTRYOIDAL. Resembling a bunch of grapes. *Etym.*, βοτρυς, *botrys*, a bunch of grapes, and ειδος, *eidos*, form.

BOWLDERS. A provincial term for large rounded blocks of stone lying on the surface of the ground, or sometimes imbedded in loose soil, different in composition from the rocks in their vicinity, and which have been therefore transported from a distance.

BRECCIA. A rock composed of angular fragments connected together by lime or other mineral substance. An Italian term.

CALC SINTER. A German name for the deposits from springs holding carbonate of lime in solution—petrifying springs. *Etym.*, *Kalk*, lime, *sintern*, to drop.

CALCAIRE GROSSIER. An extensive stratum, or rather series of strata, belonging to the Eocene tertiary period, originally found in, and specially belonging to, the Paris Basin. See Table II. E, p. 390. *Etym.*, *Calcaire*, limestone, and *grossier*, coarse.

CALCAREOUS ROCK. Limestone. *Etym.*, *Calx*, lime.

CALCEDONY. A siliceous simple mineral, uncrystallized. Agates are partly composed of calcedony.

CARBON. An undecomposed inflammable substance, one of the simple elementary bodies. Charcoal is almost entirely composed of it. *Etym.*, *Carbo*, coal.

CARBONATE of LIME. Lime combines with great avidity with carbonic acid, a gaseous acid only obtained fluid when united with water,—and all combinations of it with other substances are called *Carbonates.* All limestones are carbonates of lime, and quick lime is obtained by driving off the carbonic acid by heat.

CARBONATED SPRINGS. Springs of water, containing carbonic acid gas. They are very common, especially in volcanic countries, and sometimes contain so much gas, that if a little sugar be thrown into the water it effervesces like soda-water.

CARBONIC ACID GAS. A natural gas which often issues from the ground, especially in volcanic countries. *Etym.*, *Carbo*, coal, because the gas is obtained by the slow burning of charcoal.

CARBONIFEROUS. A term usually applied, in a technical sense, to the lowest group of strata of the secondary rocks, see Table II. L, p. 393 ; but any bed containing coal may be said to be carboniferous. *Etym.*, *Carbo*, coal, and *fero*, to bear.

CATACLYSM. A deluge. *Etym.*, κατακλυξω, *catacluso*, to deluge.

CEPHALOPODA. A class of molluscous animals, having their organs of motion arranged round their head. *Etym.*, κεφαλη, *cephale*, head, and ποδα, *poda*, feet.

Cetacea. An order of vertebrated mammiferous animals inhabiting the sea. The whale, dolphin, and narwal, are examples. *Etym.*, *Cete*, whale.

Chalk. A white earthy limestone, the uppermost of the secondary series of strata. See Table II. F, p. 390.

Chert. A siliceous mineral, approaching in character to flint, but less homogeneous and simple in texture.

Chloritic Sand. Sand coloured green by an admixture of the simple mineral chlorite. *Etym.*, κλωρος, *chloros*, green.

Coal Formation. This term is generally understood to mean the same as the Coal Measures. See Table II. L, p. 393. There are, however, 'coal formations' in all the geological periods, wherever any of the varieties of coal form a principal constituent part of a group of strata.

Coleoptera. An order of insects (Beetles) which have four wings, the upper pair being crustaceous and forming a shield. *Etym.*, κολεος, *coleos*, a shield, and πτερον, *pteron*, a wing.

Congeners. Species which belong to the same genus.

Conglomerate. Rounded water-worn fragments of rock, or pebbles, cemented together by another mineral substance, which may be of a siliceous, calcareous, or argillaceous nature. *Etym.*, *Con*, together, *glomero*, to heap.

Coniferæ. An order of plants which, like the fir and pine, bear cones or tops in which the seeds are contained. *Etym.*, *Conus*, cone, and *fero*, to bear.

Coomb. A provincial name in different parts of England for a valley on the declivity of a hill, and which is generally without water.

Cornbrash. A rubbly stone extensively cultivated in Wiltshire for growth of corn. It is a provincial term adopted by Smith. Brash is derived from breçan, Saxon, to break. See Table II. H, p. 391.

Cornstone. A provincial name for a red limestone, forming a subordinate bed in the Old Red Sandstone group.

Cosmogony, Cosmology. Words synonymous in meaning, applied to speculations respecting the first origin or mode of creation of the earth. *Etym.*, κοσμος, *kosmos*, the world, and γονη, *gonee*, generation, or λογος, *logos*, discourse.

Crag. A provincial name in Norfolk and Suffolk for a deposit, usually of gravel, belonging to the Older Pliocene period. See Table II. C, p. 389.

Crater. The circular cavity at the summit of a volcano, from which the volcanic matter is ejected. *Etym.*, *Crater*, a great cup or bowl.

CRETACEOUS. Belonging to chalk. *Etym.*, *Creta*, chalk.

CROP OUT. A miner's or mineral surveyor's term, to express the rising up or exposure at the surface of a stratum or series of strata.

CRUST OF THE EARTH. See Earth's crust.

CRUSTACEA. Animals having a shelly coating or crust which they cast periodically. Crabs, shrimps, and lobsters are examples.

CRYPTOGAMIC. A name applied to a class of plants in which the fructification, or organs of reproduction are concealed. *Etym.*, κρυπτος, *kryptos*, concealed, and γαμος, *gamos*, marriage.

CRYSTALS. Simple minerals are frequently found in regular forms, with facets like the drops of cut glass of chandeliers. Quartz being often met with in rocks in such forms, and beautifully transparent like ice, was called *rock-crystal*, κρυσταλλος, *crystallos*, being Greek for ice. Hence the regular *forms* of other minerals are called crystals, whether they be clear or opake.

CRYSTALLIZED. A mineral which is found in regular forms or crystals, is said to be crystallized.

CRYSTALLINE. The internal texture which regular crystals exhibit when broken, or a confused assemblage of ill-defined crystals. Loaf-sugar and statuary-marble have a *crystalline* texture. Sugar-candy and calcareous spar are crystallized.

CYCADEÆ. An order of plants, which are natives of warm climates, mostly tropical, although some are found at the Cape of Good Hope. They have a short stem, surmounted by a peculiar foliage, termed pinnated fronds by botanists, which spreads in a circle. The growth of these plants is by a cluster of fresh fronds shooting from the top of the stem, and pushing the former fronds outwards. These last decay down to their bases, which are broad, and remain covering the sides of the stem. The term is derived from κυκας, *cycas*, a name applied by the ancient Greek naturalist Theophrastus to a palm, said to grow in Ethiopia.

CYPERACEA. A tribe of plants answering to the English sedges; they are distinguished from grasses by their stems being solid and generally triangular, instead of being hollow and round. Together with *gramineæ* they constitute what writers on botanical geography often call *glumaceæ*.

DEBACLE. A great rush of waters, which breaking down all opposing barriers, carries forward the broken fragments of rocks, and spreads them in its course. *Etym.*, *debacler*, French, to unbar, to break up as a river does at the cessation of a long-continued frost.

Delta. When a great river before it enters the sea divides into separate streams, they often diverge and form two sides of a triangle, the sea being the base. The land included by the three lines, and which is invariably alluvial, is called a delta from its resemblance to the letter of the Greek alphabet which goes by that name Δ. Geologists extend the boundaries of the delta, so as to include all the alluvial land outside the triangle, which has been formed by the river.

Denudation. The carrying away of a portion of the solid materials of the land, by which the inferior parts are laid bare. *Etym.*, *denudo*, to lay bare.

Desiccation. The act of drying up. *Etym.*, *desicco*, to dry up.

Diagonal Stratification. For an explanation of this term, see vol. iii. p. 174.

Dicotyledonous. A grand division of the vegetable kingdom, founded on the plant having two *cotyledons* or seed-lobes. *Etym.*, δις, *dis*, double, and cotyledon.

Dikes. When a mass of the unstratified or igneous rocks, such as granite, trap, and lava appears as if injected into a great rent in the stratified rocks, cutting across the strata, it forms a dike; and as they are sometimes seen running along the ground, and projecting, like a wall, from the strata on both sides of them being worn away, they are called in the north of England and in Scotland *dikes*, the provincial name for wall. It is not easy to draw the line between dikes and veins. The former are generally of larger dimensions, and have their sides parallel for considerable distances; while veins have generally many ramifications, and these often thin away into slender threads.

Diluvium. Those accumulations of gravel and loose materials which, by some geologists, are said to have been produced by the action of a diluvian wave or deluge sweeping over the surface of the earth. *Etym.*, *diluvium*, deluge.

Dip. When a stratum does not lie horizontally, but is inclined, the point of the compass towards which it sinks is called the dip of the stratum, and the angle it makes with the horizon is called the angle of dip or inclination.

Diptera. An order of insects, comprising those which have only two wings. *Etym.*, δις, *dis* double, and πτερον, *pteron*, wing.

Dolerite. One of the varieties of the trap-rocks, composed of augite and felspar.

Dolomite. A crystalline limestone, containing magnesia as a constituent part. Named after the French geologist Dolomieu.

Dunes. Low hills of blown sand that skirt the shores of Holland,

Spain, and other countries. *Etym.*, *dun* or *dune* is an Anglo-Saxon word for hill.

EARTH'S CRUST. Such superficial parts of our planet as are accessible to human observation.

ELYTRA. The wing-sheaths, or upper crustaceous membranes, which form the superior wings in the tribe of beetles, being crustaceous appendages which cover the body and protect the true membranous wing. *Etym.*, ελυτρον, *elytron*, a sheath.

EOCENE. See explanation of this word, vol. iii. p. 55.

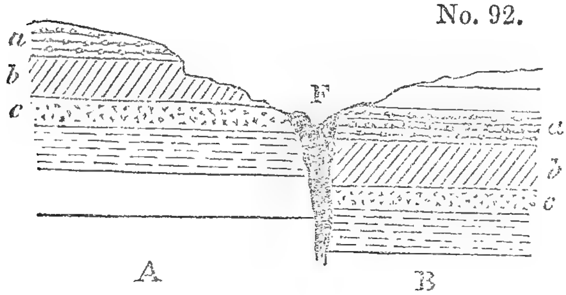
ESCARPMENT, the abrupt face of a ridge of high land. *Etym.*, *escarper*, French, to cut steep.

ESTUARIES. Inlets of the land, which are entered both by rivers and the tides of the sea. Thus we have the estuaries of the Thames, Severn, Tay, &c. *Etym. Æstus*, the tide.

FALUNS. A provincial name for some tertiary strata abounding in shells in Touraine, which resemble in lithological characters the 'crag' of Norfolk and Suffolk.

FAULT, in the language of miners, is the sudden interruption of the continuity of strata in the same plane, accompanied by a crack or fissure varying in width from a mere line to several feet, which is generally filled with broken stone, clay, &c., and such a displacement that the separated portions of the once continuous strata occupy different levels.

No. 92.



The strata *a*, *b*, *c*, &c., must at one time have been continuous, but a fracture having taken place at the fault F, either by the upheaving of the portion A, or the sinking of the portion B, the strata were so displaced, that the bed *a* in B is many feet lower than the same bed *a* in the portion A.

FAUNA. The various kinds of animals peculiar to a country constitute its FAUNA, as the various kinds of plants constitute its FLORA. The term is derived from the FAUNI, or rural deities in Roman Mythology.

FELSPAR. A simple mineral, which constitutes the chief material of many of the unstratified or igneous rocks. The white angular portions in granite are felspar. It is originally a German miners' term. *Etym.*, *feld*, field, and *spath*, a very old minera-

logical word in Germany, which seems to have been at first specially applied to a transparent kind of gypsum called selenite.

FELSPATHIC. Of or belonging to felspar.

FERRUGINOUS. Anything containing iron. *Etym.*, *ferrum*, iron.

FLOETZ ROCKS. A German term applied to the secondary strata by the geologists of that country, because these rocks were supposed to occur most frequently in flat horizontal beds. *Etym.*, *flötz*, a layer or stratum ; the word is applied in some parts of Germany to pavements and plastered floors.

FLORA. The various kinds of trees and plants found in any country constitute the Flora of that country in the language of botanists.

FLUVIATILE. Belonging to a river. *Etym.*, *fluvius*, a river.

FORMATION. A group, whether of alluvial deposits, sedimentary strata, or igneous rocks, referred to a common origin or period.

FOSSIL. All minerals used to be called fossils, but geologists now use the word only to express the remains of animals and plants found buried in the earth. *Etym.*, *fossilis*, anything that may be dug out of the earth.

GALENA, a metallic ore, a compound of lead and sulphur. It has often the appearance of highly polished lead. *Etym.*, *γαλεω*, *galeo* to shine.

GARNET. A simple mineral generally of a deep red colour, crystallized, most commonly met with in mica slate, but also in granite and other igneous rocks.

GAULT. A provincial name in the east of England for a series of beds of clay and marl, the geological position of which is between the upper and the lower greensand. See Table II. F, p. 390.

GEOLOGY, GEOGNOSY. Both mean the same thing, but with an unnecessary degree of refinement in terms, it has been proposed to call our description of the structure of the earth *geognosy*. (*Etym.* *γεα*, *gea*, earth, and *γινωσκω*, *ginosco*, to know,) and our theoretical speculations as to its formation *geology*. (*Etym.*, *γεα*, and *λογος*, *logos*, a discourse.

GLACIER. The vast accumulations of ice and hardened snow in the Alps and other lofty mountains. *Etym.* *glace*, French for ice.

GLACIS. A term borrowed from the language of fortification, where it means an easy insensible slope or declivity, less steep than a *talus*, which see.

GNEISS. A stratified primary rock, composed of the same materials as granite, but having usually a larger proportion of mica, and a laminated texture. The word is a German miner's term,

GRAMINEÆ, the order of plants to which grasses belong. *Etym.*, *gramen*, grass.

GRANITE. An unstratified or igneous rock, generally found inferior to or associated with the oldest of the stratified rocks, and sometimes penetrating them in the form of dikes and veins. It is composed of three simple minerals, felspar, quartz, and mica, and derives its name from having a coarse *granular* structure; *granum*, Latin for grain. Westminster, Waterloo, and London bridges, and the paving-stones in the carriage-way of the London streets are good examples of the most common varieties of granite.

GRAUWACKE, a German name, generally adopted by geologists for the lowest members of the secondary strata, consisting of sandstone and slate, and which form the chief part of what are termed by some geologists the *transition* rocks. The rock is very often of a grey colour, hence the name, *grau* being German for grey, and *wacke* being a provincial miner's term.

GREENSAND. Beds of sand, sandstone, limestone, belonging to the Cretaceous Period. See Table II. F, p. 390. The name is given to these beds, because they often, but not always, contain an abundance of green earth or chlorite scattered through the substance of the sandstone, limestone, &c. See vol. iii. p. 324.

GREENSTONE, a variety of trap, composed of hornblende and felspar.

GRIT, a provincial name for a coarse-grained sandstone.

GYPSUM, a mineral composed of lime and sulphuric acid, hence called also *sulphate of lime.* Plaster and stucco are obtained by exposing gypsum to a strong heat. It is found so abundantly near Paris, that Paris plaster is a common term in this country for the white powder of which casts are made. The term is used by Pliny for a stone used for the same purposes by the ancients. The derivation of it is unknown.

GYPSEOUS, of, or belonging to, gypsum.

GYROGONITES. Bodies found in fresh-water deposits, originally supposed to be microscopic shells, but subsequently discovered to be the seed-vessel of fresh-water plants of the genus *chara.* See vol. ii. p. 273, and 2d Edit. p. 280. *Etym.* γυρος, *gyros*, curved, and γονος, *gonos*, seed, on account of their external structure.

HEMIPTERA, an order of insects, so called from a peculiarity in their wings, the superior being coriaceous at the base, and membranous at the apex, ἡμισυ, *hemisu*, half, and πτερον, *pteron*, wing.

HORNBLENDE, a simple mineral of a dark green or black colour,

which enters largely into the composition of several varieties of the trap rocks.

HYDROPHYTES. Plants which grow in water. *Etym.*, ὑδωρ, *hydor*, water, and φυτον, *phyton*, plant.

HYPOGENE ROCKS. For an explanation of this term, see vol. iii. p. 374.

ICEBERG. The great masses of ice, often the size of hills, which float in the polar and northern seas. *Etym.*, ice, and *berg*, German for hill.

ICHTHYOSAURUS, a gigantic fossil marine reptile, intermediate between a crocodile and a fish. *Etym.*, ιχθυς, *ichthus*, a fish, and σαυρα, *saura*, a lizard.

INDUCTION, a consequence, conclusion or inference, drawn from propositions or principles first laid down, or from the observation and examination of phenomena.

INFUSORY ANIMALCULES. Minute living creatures generated in many *infusions;* and the term *infusoria* has been given to all such animalcules whether found in infusions or in stagnant water, vinegar, &c.

INSPISSATED. Thickened. *Etym.*, *spissus*, thick.

INVERTEBRATED ANIMALS. Animals which are not furnished with a back-bone. For a further explanation, see "Vertebrated Animals."

ISOTHERMAL. Such zones or divisions of the land, ocean, or atmosphere, which have an equal degree of mean annual warmth, are said to be isothermal, from ισος, *isos*, equal, and θερμη, *therme*, heat.

JURA LIMESTONE. The limestones belonging to the oolite group, see Table II. H, p. 391, constitute the chief part of the mountains of the Jura, between France and Switzerland, and hence the geologists of the Continent have given the name to the group.

KIMMERIDGE CLAY, a thick bed of clay, constituting a member of the Oolite Group. See Table II. H, p. 391. so called because it is found well developed at Kimmeridge in the isle of Purbeck, Dorsetshire.

LACUSTRINE, belonging to a lake. *Etym.*, *Lacus*, a lake.

LAMINÆ. Latin for plates; used in geology, for the smaller layers of which a stratum is frequently composed.

LAMANTINE. A living species of the herbivorous cetacea or whale

tribe, which inhabits the mouths of rivers on the coasts of Africa and South America; the sea-cow.

LAMELLIFEROUS. A stone composed of thin plates or leaves like paper. *Etym.*, *lamella*, the diminutive of *lamina*, plate, and *fero*, to bear.

LANDSLIP. A portion of land that has slid down in consequence of disturbance by an earthquake, or from being undermined, by water washing away the lower beds which supported it.

LAPIDIFICATION—Lapidifying process. Conversion into stone. *Etym.*, *lapis*, stone, and *fio*, to make.

LAPILLI. Small volcanic cinders. *Lapillus*, a little stone.

LAVA. The stone which flows in a melted state from a volcano.

LEUCITE. A simple mineral found in volcanic rocks, crystallized, and of a white colour. *Etym.*, λευκος, *leucos*, white.

LIAS. A provincial name, adopted in scientific language, for a particular kind of limestone, which being characterized, together with its associated beds, by peculiar fossils, is formed in this work into a particular group of the secondary strata. See Table II. I, p. 392.

LIGNIPERDOUS. A term applied to insects which destroy wood. *Etym. lignum*, wood, and *perdo*, to destroy.

LIGNITE. Wood converted into a kind of coal. *Etym.*, *lignum*, wood.

LITHODOMI. Molluscous animals which bore into solid rocks, and lodge themselves in the holes they have formed. *Etym.*, λιθος, *lithos*, stone, and *domus*, house.

LITHOLOGICAL. A term expressing the stony structure or character of a mineral mass. We speak of the lithological character of a stratum as distinguished from its zoological character. *Etym.*, λιθος, *lithos*, stone, and λογος, *logos*, discourse.

LITHOPHAGI. Molluscous animals which bore into solid stones. *Etym.*, λιθος, *lithos*, stone, and φαγειν, *phagein*, to eat.

LITTORAL. Belonging to the sea-shore. *Etym.*, *littus*, the shore.

LOAM. A mixture of sand and clay.

LYCOPODIACEÆ. Plants of an inferior degree of organization to Coniferæ, some of which they very much resemble in foliage, but all recent species are infinitely smaller. Many of the fossil species are as gigantic as recent coniferæ. Their mode of reproduction is analogous to that of ferns. In English they are called club-mosses, generally found in mountainous heaths in the north of England.

MADREPORE. A genus of corals, but generally applied to all the

corals distinguished by superficial star-shaped cavities. There are several fossil species.

MAGNESIAN LIMESTONE. An extensive series of beds lying in geological position, immediately above the coal-measures, so called because the limestone, the principal member of the series, contains much of the earth magnesia as a constituent part. See Table II. K, p. 392.

MAMMILLARY. A surface which is studded over with rounded projections. *Etym.*, *mammilla*, a little breast or pap.

MAMMIFEROUS. Animals which give suck to their young. *Etym.*, *mamma*, a breast, and *fero*, to bear.

MAMMOTH. An extinct species of the elephant (E. primigenius), of which the fossil bones are frequently met with in various countries. The name is of Tartar origin, and is used in Siberia for animals that burrow underground.

MARL. A mixture of clay and lime; usually soft, but sometimes hard, in which case it is called indurated marl.

MARSUPIAL ANIMALS. A tribe of quadrupeds having a sack or pouch under the belly, in which they carry their young. The kangaroo is a well-known example. *Etym.*, *marsupium*, a purse.

MASTODON. A genus of fossil extinct quadrupeds allied to the elephant. So called from the form of the hind teeth or grinders, which have their surface covered with conical mammillary crests. *Etym.*, μαστος, *mastos*, mammilla or little pap, and οδων, *odon*, tooth.

MATRIX. If a simple mineral or shell, in place of being detached, be still fixed in a portion of rock, it is said to be in its matrix. *Matrix*, womb.

MECHANICAL ORIGIN, Rocks of. When rocks are composed of sand, pebbles, or fragments, to distinguish them from those of an uniform crystalline texture, which are of chemical origin.

MEDUSÆ. A genus of marine radiated animals, without shells; so called because their organs of motion spread out like the snaky hair of the fabulous Medusa.

MEGALOSAURUS. A fossil gigantic amphibious animal of the saurian or lizard and crocodile tribe. *Etym.*, μεγαλη, *megale*, great, and σαυρα, *saura*, lizard.

MEGATHERIUM. A fossil extinct quadruped, resembling a gigantic sloth. *Etym.*, μεγα, *mega*, great, and θηριον, *therion*, wild-beast.

MELASTOMA. A genus of MELASTOMACEA, an order of plants of the evergreen tree, and shrubby exotic kinds. *Etym.*, μελας, *melas*, black, and στομα, *stoma*, mouth; because the fruit of one of the species stains the lips.

Mesotype. A simple mineral, white, and needle-shaped, one of the Zeolite family, frequently met with in the trap rocks.

Metamorphic Rocks. For an explanation of this term, see vol. iii. p. 374.

Mica. A simple mineral, having a shining silvery surface, and capable of being split into very thin elastic leaves or scales. It is often called *talc* in common life, but mineralogists apply the term talc to a different mineral. The brilliant scales in granite are mica. *Etym.*, *mico*, to shine.

Mica-Slate, Mica-Schist, Micaceous Schistus. One of the lowest of the stratified rocks, belonging to the primary class, which is characterized by being composed of a large proportion of mica, united with quartz.

Miocene. See an explanation of this term, vol. iii. p. 54.

Molasse. A provincial name for a soft, green sandstone, associated with marl and conglomerates, belonging to the Miocene tertiary period, extensively developed in the lower country of Switzerland. See vol. iii. p. 212.

Molluscæ, Molluscous Animals. Animals, such as shell-fish, which, being devoid of bones, have soft bodies. *Etym.*, *mollis*, soft.

Monitor. An animal of the saurian or lizard tribe, species of which are found in both the fossil and recent state.

Monocotyledonous. A grand division of the vegetable kingdom, founded on the plant having only one *cotyledon*, or seed-lobe. *Etym.*, *μονος*, *monos*, single.

Moschus. The quadruped resembling the chamois or mountain-goat, from which the perfume musk is obtained.

Mountain Limestone. A series of limestone strata, of which the geological position is immediately below the coal measures, and with which they also sometimes alternate. See Table II. L, p. 393.

Moya. A term applied in South America to mud poured out from volcanos during eruptions.

Muriate of Soda. The scientific name for common culinary salt, because it is composed of muriatic acid and the alkali soda.

Musaceæ. A family of tropical monocotyledonous plants, including the banana and plantains.

Muschelkalk. A limestone which, in geological position, belongs to the red sandstone group. This formation has not yet been found in England, and the German name is adopted by English geologists. The word means shell-limestone: *muschel*, shell, and *kalkstein*, limestone. See Table II. K, p. 392.

Naphtha. A very thin, volatile, inflammable, and fluid mineral

substance, of which there are springs in many countries, particularly in volcanic districts.

NENUPHAR. A yellow water-lily.

NEW RED SANDSTONE. A series of sandy, argillaceous, and often calcareous strata, the predominant colour of which is brick-red, but containing portions which are of a greenish grey. These occur often in spots and stripes, so that the series has sometimes been called the variegated sandstone. The European formation so called lies in a geological position immediately above the coal-measures. See Table II. K, p. 392.

NODULE. A rounded irregular-shaped lump or mass. *Etym.*, diminutive of *nodus*, knot.

NORMAL GROUPS. Groups of certain rocks taken as a rule or standard. *Etym. norma*, rule or pattern.

NUCLEUS. A solid central piece, around which other matter is collected. The word is Latin for kernel.

NUMMULITES. An extinct genus of the Order of Molluscous animals, called Cephalopoda, of a thin lenticular shape, internally divided into small chambers. *Etym.*, *nummus*, Latin for money, and λιθος, *lithos*, stone, from its resemblance to a coin.

OBSIDIAN. A volcanic product, or species of lava, very like common green bottle-glass, which is almost black in large masses, but semi-transparent in thin fragments. Pumice-stone is obsidian in a frothy state; produced most probably by water that was contained in or had access to the melted stone, and converted into steam. There are very often portions in a mass of solid obsidian, which are partially converted into pumice.

OGYGIAN DELUGE. A general inundation of fabulous history, which is supposed to have taken place in the reign of Ogyges in Attica, whose death is fixed in Blair's Chronological Tables in the year 1764 before Christ.

OLD RED SANDSTONE. A stratified rock belonging to the Carboniferous group. See Table L, p. 393.

OLIVINE. An olive-coloured, semi-transparent, simple mineral, very often occurring in the forms of grains and of crystals in basalt and lava.

OOLITE, Oolitic. A limestone, forming a characteristic feature of a group of the secondary strata. See Table II. H, p. 391. It is so named, because it is composed of rounded particles, like the roe or eggs of a fish. *Etym.* ωον, *oon*, egg, and λιθος, *lithos*, stone.

OPALIZED WOOD. Wood petrified by siliceous earth, and acquiring a structure similar to the simple mineral called opal.

OPHIDIOUS REPTILES. Vertebrated animals, such as snakes and serpents. *Etym.*, οφις, *ophis*, a serpent.

ORGANIC REMAINS. The remains of animals and plants; *organized* bodies, found in a fossil state.

ORTHOCERATA. An extinct genus of the order of Molluscous Animals, called Cephalopoda, that inhabited a long chambered, conical shell, like a straight horn. *Etym.*, ορθος, *orthos*, straight, and κερας, *ceras*, horn.

OSSEOUS BRECCIA. The cemented mass of fragments of bones of extinct animals found in caverns and fissures. *Osseus* is a Latin adjective, signifying bony.

OUTLIERS. When a portion of a stratum occurs at some distance, detached from the general mass of the formation to which it belongs, some practical mineral surveyors call it an *outlier*, and the term is adopted in geological language.

OVATE. The shape of an egg. *Etym.*, *ovum*, egg.

OVIPOSITING. The laying of eggs.

OXYGEN. One of the constituent parts of the air of the atmosphere; that part which supports life. For a further explanation of the word, consult elementary works on chemistry.

OXIDE. The combination of a metal with oxygen; rust is oxide of iron.

PACHYDERMATA. An order of quadrupeds, including the elephant, rhinoceros, horse, pig, &c., distinguished by having thick skins. *Etym.* παχυς, *pachus*, thick, and δερμα, *derma*, skin or hide.

PACHYDERMATOUS. Belonging to pachydermata.

PALÆOTHERIUM, PALEOTHERE. A fossil extinct quadruped, belonging to the order pachydermata, resembling a pig or tapir, but of great size. *Etym.* παλαιος, *palaios*, ancient, and θηριον, *therion*, wild beast.

PELAGIAN, PELAGIC. Belonging to the *deep* sea. *Etym. pelagus*, sea.

PEPERINO. An Italian name for a particular kind of volcanic rock, formed, like tuff, by the cementing together of volcanic sand, cinders, or scoriæ, &c.

PETROLEUM. A liquid mineral pitch, so called because it is seen to ooze like oil out of the rock. *Etym. petra*, rock, and *oleum*, oil.

PHANEROGAMIC PLANTS. A name given by Linnæus to those plants

in which the reproductive organs are apparent. *Etym.* φανερος, *phaneros*, evident, and γαμος, *gamos*, marriage.

PHYSICS. The department of science, which treats of the properties of natural bodies, laws of motion, &c., sometimes called Natural philosophy and mechanical philosophy. *Etym.* φυσις, *physis*, nature.

PHYTOLOGY, PHYTOLOGICAL. The department of science which relates to plants—synonymous with botany and botanical. *Etym.* φυτον, *phyton*, plant, and λογος, *logos*, discourse.

PHYTOPHAGOUS. Plant eating. *Etym.* φυτον, *phyton*, plant, and φαγειν, *phagein*, to eat.

PISLIAR, a misprint for PISTIA, in vol. ii. p. 98, 1st ed., p. 102, 2d ed. The plant mentioned by Malte-Brun is probably the *Pistia stratiotes*, a floating plant, related to English duck-weed, but very much larger.

PISOLITE. A stone possessing a structure like an agglutination of pease. *Etym.* πισον, *pison*, pea, and λιθος, *lithos*, stone.

PIT COAL. Ordinary coal; called so because it is obtained by sinking pits in the ground.

PITCH STONE. A rock of an uniform texture, belonging to the unstratified and volcanic classes, which has an unctuous appearance, like indurated pitch.

PLASTIC CLAY. One of the beds of the Eocene tertiary period (see Table II. E, p. 390.) It is so called because it is used for making pottery. *Etym.* πλασσω, *plasso*, to form or fashion.

PLESIOSAURUS. A fossil extinct amphibious animal, resembling the saurian, or lizard and crocodile tribe. *Etym.* πλησιον, *plesion*, near to, and σαυρα, *saura*, a lizard.

PLIOCENE. See explanation of this term, vol. iii. p. 53.

PLUTONIC ROCKS. For an explanation of this term, see vol. iii. p. 353.

POLYPARIA. CORALS. A numerous class of invertebrated animals, belonging to the great division called Radiata.

PORPHYRY. An unstratified or igneous rock. The term is as old as Pliny, and was applied to a red rock with small angular white bodies diffused through it, which are crystallized felspar, brought from Egypt. The term is hence applied to every species of unstratified rock, in which detached crystals of felspar are diffused through a base of other mineral composition. *Etym.* πορφυρα, *porphyra*, purple.

PORTLAND LIMESTONE, PORTLAND BEDS. A series of limestone strata, belonging to the upper part of the Oolite group (see Table II.

H, p. 391.), found chiefly in England, in the Island of Portland on the coast of Dorsetshire. The great supply of the building stone used in London is from these quarries.

POZZUOLANA. Volcanic ashes, largely used as mortar for buildings, similar in nature to what is called in this country Roman cement. It gets its name from Pozzuoli, a town in the bay of Naples, from which it is shipped in large quantities to all parts of the Mediterranean.

PRODUCTÆ. An extinct genus of fossil bivalve shells, occurring only in the older of the secondary rocks. It is closely allied to the living genus Terebratula.

PUBESCENCE. The soft hairy down on insects. *Etym.*, *pubesco*, the first growth of the beard.

PUMICE.—A light spongy lava, of a white colour, produced by gases, or watery vapour getting access to the particular kind of glassy lava called obsidian, when in a state of fusion—it may be called the froth of melted volcanic glass. The word comes from the Latin name of the stone, *pumex*.

PURBECK LIMESTONE, PURBECK BEDS. Limestone strata belonging to the Wealden group. See Table II. G, p. 390.

PYRITES (Iron). A compound of sulphur and iron, found usually in yellow shining crystals like brass, and in almost every rock stratified and unstratified. The shining metallic bodies, so often seen in common roofing slate, are a familiar example of the mineral. The word is Greek, and comes from *πυρ*, *pyr*, fire, because, under particular circumstances, the stone produces spontaneous heat and even inflammation.

QUADRUMANA. The order of mammiferous animals to which apes belong. *Etym.*, *quadrus*, a derivation of the Latin word for the number four, and *manus*, hand,—the four feet of those animals being in some degree usable as hands.

QUA-QUA-VERSAL DIP. The dip of beds to all points of the compass around a centre, as in the case of beds of lava round the crater of a volcano. *Etym.*, *quâ-quâ versum*, on every side.

QUARTZ. A German provincial term, universally adopted in scientific language, for a simple mineral composed of pure silex, or earth of flints; rock-crystal is an example.

RED MARL. A term often applied to the New Red Sandstone, which

is the principal member of the Red Sandstone group. See Table II. K, p. 392.

RETICULATE. A structure of cross lines, like a net, is said to be reticulated, from *rete*, a net.

ROCK SALT. Common culinary salt, or muriate of soda, found in vast solid masses or beds, in different formations, extensively in the New Red Sandstone formation, as in Cheshire, and it is then called *rock*-salt.

RUMINANTIA. Animals which ruminate or chew the cud. *Etym.*, the Latin verb *rumino*, meaning the same thing.

SACCHAROID, SACCHARINE. When a stone has a texture resembling that of loaf-sugar. *Etym.*, σακκαρ, *sacchar*, sugar, and ειδος, *eidos*, form.

SALIENT ANGLE. In a zigzag line, *a a* are the salient angles, *b b* the re-entering angles.

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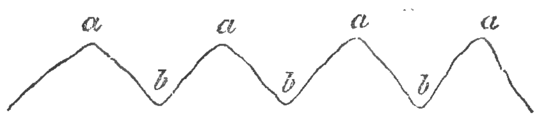

Etym., *salire*, to leap or bound forward.

SALT SPRINGS. Springs of water containing a large quantity of common salt. They are very abundant in Cheshire and Worcestershire, and culinary salt is obtained from them by mere evaporation.

SANDSTONE. Any stone which is composed of an agglutination of grains of sand, which may be either calcareous or siliceous.

SAURIAN. Any animal belonging to the lizard tribe. *Etym.*, σαυρα, *saura*, a lizard.

SCHIST. Synonymous with slate. *Etym.*, part of the Latin verb *scindo*, to split, from the facility with which slaty rocks may be split into thin plates.

SCHISTOSE ROCKS. Synonymous with *slaty* rocks.

SCORIÆ. Volcanic cinders. The word is Latin for cinders.

SEAMS. Thin layers which separate two strata of greater magnitude.

SECONDARY STRATA. An extensive series of the stratified rocks which compose the crust of the globe, with certain characters in common, which distinguish them from another series below them, called *primary*, and from a third series above them called *tertiary*. See vol. iii. p. 324, and Table II. p. 390.

SECULAR REFRIGERATION. The periodical cooling and consolidation of the globe, from a supposed original state of fluidity from heat. *Sæculum*, age or period.

SEDIMENTARY ROCKS, are those which have been formed by their

materials having been thrown down from a state of suspension or solution in water.

Selenite. Crystallized gypsum, or sulphate of lime—a simple mineral.

Septaria. Flattened balls of stone, generally a kind of iron-stone, which, on being split, are seen to be separated in their interior into irregular masses. *Etym.*, *septa*, inclosures.

Serpentine. A rock usually containing much magnesian earth, for the most part unstratified, but sometimes appearing to be an altered or metamorphic stratified rock. Its name is derived from frequently presenting contrasts of colour, like the skin of some serpents.

Shale. A provincial term, adopted in geological science, to express an indurated slaty clay. *Etym.*, German *schalen*, to peal, to split.

Shell Marl. A deposit of clay, peat, and other substances mixed with shells, which collects at the bottom of lakes.

Shingle. The loose and completely water-worn gravel on the sea-shore.

Silex. The name of one of the pure earths, being the Latin word for *flint*, which is wholly composed of that earth. French geologists have applied it as a generic name for all minerals composed entirely of that earth, of which there are many of different external forms.

Silica. One of the pure earths. *Etym.*, *silex*, flint, because found in that mineral.

Silicate. A chemical compound of silica and another substance, such as silicate of iron. Consult elementary works on chemistry.

Siliceous. Of or belonging to the earth of flint. *Etym.*, silex, which see. A siliceous rock is one mainly composed of silex.

Silicified. Any substance that is petrified or mineralized by *siliceous* earth.

Silt. The more comminuted sand, clay, and earth, which is transported by running water. It is often accumulated by currents in banks. Thus we speak of the mouth of a river being silted up when its entrance into the sea is impeded by such accumulation of loose materials.

Simple Mineral. Individual mineral substances, as distinguished from rocks, which last are usually an aggregation of simple minerals. They are not simple in regard to their nature, for when subjected to chemical analysis, they are found to consist of a variety of different substances. Pyrites is a simple mineral in

the sense we use the term, but it is a chemical compound of sulphur and iron.

SOLFATARA. A volcanic vent from which sulphur, sulphureous, watery, and acid vapours and gases are emitted.

SPORULES. The reproductory corpuscula (minute bodies) of cryptogamic plains. *Etym.*, σπορα, *spora*, a seed.

STALACTITE. When water holding lime in solution deposits it as it drops from the roof of a cavern, long rods of stone hang down like icicles, and these are called *stalactites*. *Etym.*, σταλαζω, *stalazo*, to drop.

STALAGMITE. When water holding lime in solution drops on the floor of a cavern, the water evaporating leaves a crust composed of layers of limestone; such a crust is called *stalagmite*, from σταλαγμα, *stalagma*, a drop, in opposition to *stalactite*, which see.

STILBITE. A white crystallized simple mineral, one of the Zeolite family, frequently included in the mass of the trap rocks.

STRATIFIED. Rocks arranged in the form of *strata*, which see.

STRATIFICATION. An arrangement of rocks in *strata*, which see.

STRATUM, STRATA. When several rocks lie like the leaves of a book, one upon another, each individual forms a *stratum*;—strata is the plural of the word. *Etym.*, *stratum*, part of a Latin verb signifying to strew or lay out.

STRIKE. The direction or line of bearing of strata, which is always at right angles to their prevailing dip. For a fuller explanation, see vol. iii. p. 346.

SUBAPENNINES. Low hills which skirt or lie at the foot of the great chain of the Apennines in Italy. The term Subapennine is applied geologically to a series of strata of the Older Pliocene period.

SYENITE. A kind of granite, so called because it was brought from Syene in Egypt. For geological acceptation of the term, see vol. iii. p. 358.

SYNCLINAL AXIS. See explanation of this term, vol. iii. p. 293.

TALUS. When fragments are broken off by the action of the weather from the face of a steep rock, as they accumulate at its foot, they form a sloping heap, called a talus. The term is borrowed from the language of fortification, where *talus* means the outside of a wall of which the thickness is diminished by degrees, as it rises in height, to make it the firmer.

TARSI. The feet in insects, which are articulated, and formed of five or a less number of joints.

TERTIARY STRATA. A series of sedimentary rocks, with characters

which distinguish them from two other great series of strata,—the secondary and primary, which lie *beneath* them. See Tables, p. 61, &c.

TESTACEA. Molluscous animals, having a shelly covering. *Etym.*, *testa*, a shell, such as snails, whelks, oysters, &c.

THIN OUT. When a stratum, in the course of its prolongation in any direction, becomes gradually less in thickness, the two surfaces approach nearer and nearer; and when at last they meet, the stratum is said to thin out, or disappear.

TRACHYTE. A variety of lava essentially composed of glassy felspar, and frequently having detached crystals of felspar in the base or body of the stone, giving it the structure of porphyry. It sometimes contains hornblende and augite; and when these last predominate, the trachyte passes into the varieties of trap called greenstone, basalt, dolorite, &c. The term is derived from *τρακυς*, *trachus*, rough, because the rock has a peculiar rough feel.

TRAP and TRAPPEAN ROCKS. Volcanic rocks composed of felspar, augite, and hornblende. The various proportions and state of aggregation of these simple minerals, and differences in external forms, give rise to varieties, which have received distinct appellations, such as basalt, amygdaloid, dolorite, greenstone, and others. The term is derived from *trappa*, a Swedish word for stair, because in Sweden the rocks of this class often occur in large tabular masses, rising one above another, like the steps of a staircase. For further explanation, see vol. iii. p. 359.

TRAVERTIN. A limestone, usually hard and semi-crystalline, deposited from the water of springs holding lime in solution. The word is Italian, and a corruption of the term *Tiburtinus*, the stone being formed in great quantity by the river Anio, at Tibur, near Rome, and hence it was called by the ancients *Lapis Tiburtinus*.

TROPHI, of Insects. Organs which form the mouth, consisting of an upper and under lip, and comprising the parts called mandibles, maxillæ, and palpi.

TUFF, or TUFO. An Italian name for a variety of volcanic rock, of an earthy texture, seldom very compact, and composed of an agglutination of fragments of scoriæ and loose matter ejected from a volcano.

TUFACEOUS. A rock with the texture of tuff or tufo, which see.

TURBINATED. Shells which have a spiral or screw-form structure. *Etym.*, *turbinatus*, made like a top.

VEINS, Mineral. Cracks in rocks filled up by substances different from the rock, which may either be earthy or metallic. Veins are sometimes many yards wide; and they ramify or branch off into innumerable smaller parts, often as slender as threads, like the veins in an animal, and hence their name.

VERTEBRATED ANIMALS. A great division of the animal kingdom, including all those which are furnished with a back-bone, as the mammalia, birds, reptiles, and fishes. The separate joints of the back-bone are called *vertebræ*, from the Latin verb *verto*, to turn.

VESICLE. A small circular inclosed space, like a little bladder. *Etym.*, diminutive of *vesica*, Latin for a bladder.

VOLCANIC BOMBS. Volcanos throw out sometimes detached masses of melted lava, which, as they fall, assume rounded forms (like bomb-shells), and are often elongated into a pear shape.

VOLCANIC FOCI. The subterranean centres of action in volcanos, where the heat is supposed to be in the highest degree of energy.

ZEOLITE. A family of simple minerals, including stilbite, mesotype, analcime, and some others, usually found in the trap or volcanic rocks. Some of the most common varieties swell or boil up when exposed to the blow-pipe, and hence the name of ξεω, *zeo*, to froth, and λιθος, *lithos*, stone.

ZOOPHYTES. Corals, sponges, and other aquatic animals allied to them, so called because, while they are the habitation of animals, they are fixed to the ground, and have the forms of plants. *Etym.*, ζωον, *zoon*, animal, and φυτον, *phyton*, plant.

INDEX.

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THE END.

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